Universidad Nacional Autónoma de México

Facultad de Ingeniería

Computación Gráfica e Interacción Humano Computadora

Grupo 2

Simulation of the climatic change effects in Mexico

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Ciudad de México, México

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Hoja de evidencias

Simulación de los efectos del cambio climático en México

Lista de números de cuenta

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Índice

1. Justification

In recent years, we have witnessed a significant global impact on global warming and climate change, and our country Mexico is no exception. Currently, we have observed that people care very little, or almost not at all, about taking care of the environment, both on a personal and corporate level. We have become increasingly materialistic, resulting in higher production and consequently, greater pollution. This has led to the disruption of the climate, with unexpected rainfall during non-rainy seasons and escalating heat as the years go by. Therefore, we aim to raise awareness among the people in our country by creating a computer-generated simulation with graphics. Through this simulation, individuals can visualize the consequences of actions such as littering on the streets and in drains, and understand how these actions can impact the future. The goal is to encourage users to think more carefully about their choices and prevent the virtual environment from becoming a reality in our actual lives.

2. General Objective

"To raise awareness among users about the consequences that climate change can bring if the care for the environment continues to be ignored, and to encourage them to actively participate in the planet's preservation."

3. Especific Objetive

The student will apply a structured methodology for the development of an interactive graphical project that includes: problem statement, analysis, design, coding, and system testing. The student will use various technologies within the field of computer graphics and human-computer interface design for the representation and manipulation of data in a specific application area, such as medicine, physics, mathematics, geosciences, biology, mechanics, telecommunications, psychology, cinematography, among others, for educational, entertainment, and/or research purposes.

4. Abstract

This report presents the final delivery of our project. We will cover various points to showcase everything accomplished throughout the course and demonstrate how we pursued the objective of simulating the effects of climate change in Mexico. We will explain the practical methodology used, the experiments conducted, and the final results obtained by simulating the consequences of climate transformation, such as diseases, pollution, waste excess, and so on. Additionally, this project also includes various approaches to raise user awareness in order to generate an impact with the work performed. Subsequently, individual conclusions about teamwork will be included, and finally, a link to a demonstrative video of our project's functionality will be provided..

5. Introduction

Climate change is one of the greatest challenges facing Mexico today. The flow of information on this issue is limited, compounded by society's lack of interest and inadequate political measures implemented to mitigate the negative effects. Some of these effects include:

- The increase in global temperature has led to a rise in the frequency and severity of extreme weather events in Mexico, such as droughts, floods, and hurricanes.
- Climate change has impacted Mexico's biodiversity, particularly in coastal ecosystems, jungles, and forests.
- Agricultural production has been affected by water scarcity and rising temperatures.
- Climate change has increased the vulnerability of indigenous and rural communities in Mexico.

On the other hand, some of the public policies implemented regarding climate change are as follows:

- The increase in global temperature has led to a rise in the frequency and severity of extreme weather events in Mexico, such as droughts, floods, and hurricanes.

- Climate change has impacted Mexico's biodiversity, particularly in coastal ecosystems, jungles, and forests.
- Agricultural production has been affected by water scarcity and rising temperatures.
- Climate change has increased the vulnerability of indigenous and rural communities in Mexico.

Despite the efforts made, Mexico still faces significant challenges in its fight against climate change, including lack of financing and resources, and the need to enhance coordination and collaboration across different sectors. However, the country also has the opportunity to lead the transition towards a low-carbon and climate-resilient economy in Latin America, leveraging its position as one of the largest economies in the region and its rich biodiversity.

5.1. Taking an approach to pollution

5.1.1. Livestock farming

Livestock farming is a crucial economic activity for our country. On average, it contributes 39.7

5.1.2. Agriculture

Agriculture is a primary economic activity of our country. Unfortunately, how this practice is carried out to satisfy the demand for food in our country is not entirely healthy, since pesticides and insecticides are used that cause air and water pollution. According to [8], ït is estimated that only 1 % of the pesticides used preventively in agriculture, regardless of whether or not a pest occurs, reaches the crops, the rest contaminates the soil, air and, mainly, the water bodies. In the Irrigation District studied, the presence of 25 pesticides is reported; the 13 most widely used include five triazines, four carbamates and four organochlorine pesticides, all of them in concentrations that exceed the limits of the Official Mexican Standard (nom-127-ssa1-1994) for water for human use and consumption". In addition, "... it is estimated that of the pesticides used in agriculture in a preventive manner, regardless of whether or not a pest occurs, only 1 % reaches the crops, the rest contaminates the soil, air

and, mainly, the water bodies". This is very worrying because pesticides with a concentration that exceeds the established standards are used every day and only 1 % is really used, the remaining 99 % is contamination of the most important elements for us, at an environmental level. and economic: Bodies of water and soil.

5.1.3. Volcanic Activity

The volcanic activity of Popocatépetl has been a problem for Mexico City and the State of Mexico. The expulsion of volcanic ash implies health problems for the population that has close contact with the volcano. According to [6], "the ash acts as a foreign body, with the sulfur dioxide crystals directly affecting the conjunctiva and corneas, producing abrasions, in addition to the irritant effect. For their part, the microelements present in the ash, such as volcanic bromine, can form part of the spring water and during purification generate trihalomethanes, which are carcinogenic compounds. It is due to the above and to the fact that Popocatépetl's activity has become a little more frequent that we should not stop considering it as a present contaminant.

5.1.4. Oil

For many years, Mexico has been a petroleum-dependent country, meaning that the stability of its economy relies largely on the extraction and exportation of crude oil. This market was monopolized for many years by the company PEMEX. The lack of investment in technology to improve extraction processes and corruption have led to PEMEX being involved in hundreds of environmental incidents. Between 2008 and 2021, PEMEX caused pollution equivalent to the size of Chapultepec Forest. The problem becomes even more concerning when it is reported that many of these incidents have gone unaddressed for over 10 years, resulting in irreparable damage to the ecosystem. During the oil extraction process, a significant amount is spilled, contaminating the subsurface and the air. [9]

5.1.5. Electronic Components

In recent years, the demand for electronic components has experienced an impressive boom. On one hand, it is beneficial for the evolution and progress of humanity, leading to

increased productivity and the opening of new markets, which in turn generates new job opportunities. However, the amount of pollution generated by the production of electronic components is concerning, especially when considering their short lifespan.

It is estimated that 50 million tons of electronic waste are discarded each year, and this waste is difficult to recycle. In Mexico, we do not yet have a well-established culture regarding the disposal of electronic components (or even proper waste separation). This poses an even more serious problem, as people often throw their electronic components into the same trash bin as food, plastic, and other substances. This results in the contamination of soil and bodies of water with heavy metals such as mercury, lead, cadmium, chromium, arsenic, or antimony. [10]

6. Practical Methodology

6.1. SCRUM

For the development of this project, the methodology known as '*SCRUM*" was followed. This methodology is an agile framework that focuses on the incremental delivery of software through interactions called "sprints". In other words, a method was followed in which deliveries were iterative and incremental, indicating that the program was developed in incremental and functional versions throughout each sprint. This allowed us to obtain early feedback to adjust approaches based on the identified needs. It is worth mentioning that we divided ourselves into specialized teams (according to our areas of expertise) to work in parallel, maintaining efficient communication to avoid versioning conflicts. The following is an example list of how the project was divided:

1. Product Backlog: We identified and prioritized all the functionalities, objects, textures, and animations that needed to be included in the project. These were added to the Product Backlog, which is an ordered list of items to be developed.

2. Sprint Planning: At the beginning of each Sprint, we selected a set of items from the Product Backlog to work on during that Sprint. These items were decomposed into smaller tasks, and efforts required to complete them were estimated.

3. Daily Scrum: We conducted daily work sessions (stand-ups) to discuss progress, identify potential obstacles, and adjust the plan as needed. During these sessions, we marked the tasks completed, those in progress, and the ones planned for the next steps.

4. Sprint: During the sprint, which has a defined duration, we worked on implementing the selected functionalities, objects, textures, and animations. The modeling, texturing, and animation of the objects in the virtual environment were carried out.

5. Sprint Review: At the end of each sprint, we reviewed the progress made. Additionally, we analyzed and gathered information about the work completed. This allowed us to adjust the requirements and priorities for the subsequent sprints.

6. Sprint Retrospective: In this section, we analyzed what was done well, what can be improved, and how to optimize the process. We identified the lessons learned and made adjustments to the way we work.

7. Next Sprint: Based on the feedback received and the established priorities, we selected a new set of items from the Product Backlog for the next sprint and repeated the cycle.

6.2. Work division

It is important to emphasize that the Scrum methodology can vary depending on the specific project. In this case, general concepts were followed and applied to the work done. In our case, although we all attempted to cover different areas of the project, in the end, the work was divided among the following specialized teams:

- Modeling and Texturing Team: Zuriel Zárate García y Fernando Medina Segura
- Animation and Lighting Team: Carlos Eduardo Recinas Barajas y Diego Pérez González
- Programming Team: Carlos Eduardo Recinas Barajas y Johan Ariel Ferrer Trejo
- Development Management Team: Zuriel Zárate García y Diego Pérez González
- Design and Quality Control Team: Fernando Medina Segura y Johan Ariel Ferrer Trejo.

As can be seen, the team size allowed for multiple members to take on different areas simultaneously, which proved to be faster and easier for development.

6.3. Gantt chart

Below is the diagram used for the project development throughout the semester, which serves to keep track of the activities carried out during a project.

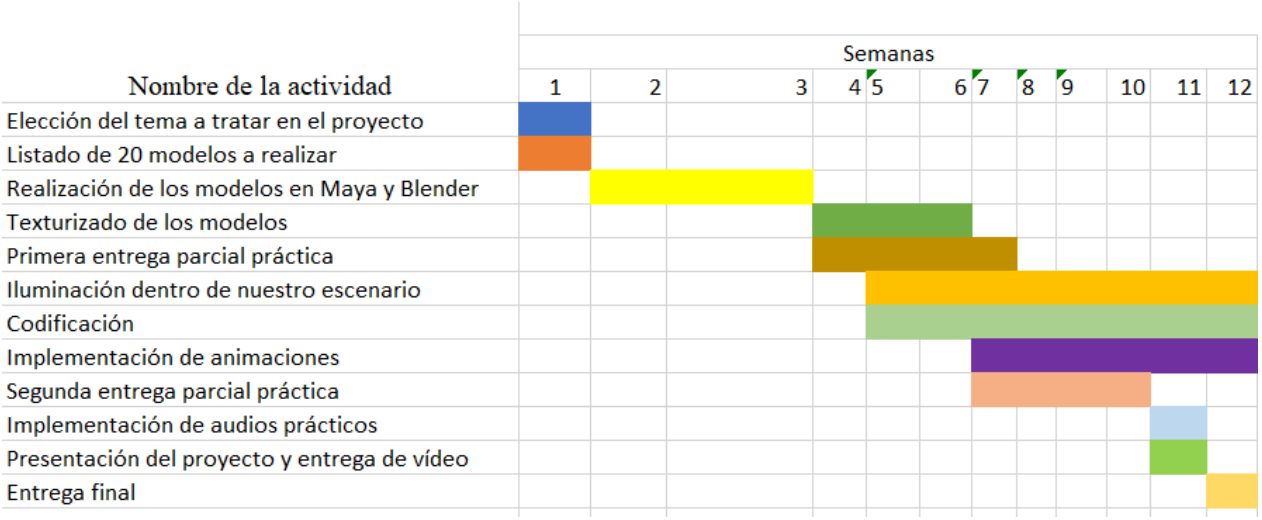

Figura 1: Gantt chart

6.4. Conceptualization and Idea

For the idea, the virtual environment that we would create was discussed as a team to create awareness in the user, especially Mexicans, about pollution and climate change. At the beginning it was thought to have two different scenarios, the first where everything is clean and the second where everything is contaminated, but to have a better contrast, it was decided to combine both scenarios into one, in such a way that the user sees what happens if we live in an environment full of garbage, pests like rats, and live the effects of climate change, and imply that it is better to live cleanly and generate as little garbage as possible to avoid the effects of pollution such as climate change. There is a street divided into a clean part, with solar panels, ecological transport such as bicycles, garbage cans, manicured trees, and on the dirty side we have the other contrast, which uses only conventional energy such as light poles, polluting transport such as cars, garbage scattered on the sidewalk, harmful fauna and pests such as rats, and neglected flora such as felled trees, favoring a hotter climate. The environment has several posters, both technical that show the interactions that the user can carry out, and posters of the environment, where the user is displayed information about the

scenario in which he is located and the user is sought to raise awareness in the world. about caring for the environment and avoiding the effects of climate change. The user can interact with an animated character so that he can visit the environment through this character. The environment also has audio that explains to the user about the environment in which they are, what they can do on stage and what we seek to give the user as a message, and other background audio so that the user feels more comfortable and natural in the virtual environment.

6.5. Modeling

The models used in the development of our project are listed below:

6.5.1. Modelos generales

1. Departamentos: Al ser un entorno citadino, se busca que el usuario sienta que está en una ciudad.

2. Edificios América: Representan edificios corporativos, los cuales se encuentran en cualquier ciudad importante.

3. Hospitales: Los hospitales pueden ser mas demanados por enfermedades causadas por la contaminación.

4. Calle principal: Es la base del entorno virtual.

5. Tortillerías: Al querer darle un mejor mensaje a nuestro país, México, decidimos agregar elementos habituales de un poblado mexicano como lo son las tortillerías.

6. Tiendas de abarrotes: Al igual que las tortillerías, las tiendas de abarrotes son establecimientos conocidos por los mexicanos, y de igual forma pueden verse afectados por la contaminación y la falta de agua.

7. Carteles: Son el medio por el cuál se busca que el usuario interáctue y darle el mensaje al usuario.

8. Postes de luz: Toda ciudad cuenta con postes de luz que energizan la ciudad, pero al ser energías no renovables, propician a generar contaminación.

9. Luna: El entorno al contar con un cubemapping de noche, se busca que el usuario sienta que realmente es de noche en la calle.

10. Personaje: Es el medio por el que el usuario va a interactuar con el resto del escenario virtual. Tendrá dos tipos de vistas, primera persona y tercera persona (Modelo sacado de Mixamo).

6.5.2. Modelos del lado limpio

1. Bicicletas: Al ser un medio de transporte no contaminante, son medios ideales para desplazarse de un punto a otro.

2. Bancas: Si el entorno es limpio, puede ser aprovechado para recreación y una mejor interacción social.

3. Paneles Solares: Son un tipo de energía más sustentable porque se aprovecha la energía natural proveniente del Sol, y se genera menor contaminación.

4. Botes de basura: Si una ciudad cuenta con una buena cantidad de botes de basura, la gente no tendria pretexto para seguir tirando basura en la calle, evitando que se generen focos de infecciones y plagas, y hay un mayor cuidado ambiental.

5. Árboles sanos: La presencia de árboles en una ciudad es un buen concepto para regular la temperatura del entorno donde vivimos, evitando que se generen calores extremos, además, la flora y fauna esta mejor cuidada en un ambiente limpio.

6.5.3. Modelos del lado contaminado

1. Ratas: Las ratas son plagas portadoras de enfermedades, entre mayor basura haya en un lugar, se propicia a que haya mas animales de este tipo, haciendo que la gente se enferme. (Modelo sacado de internet)

2. Basura: La basura en cualquier parte del mundo es un problema, y en México no es la excepción, la basura trae problemas ambientales, sociales, económicos, éticos y políticos en cualquier lado, y son el factor más grande por el que hay contaminación y cambio climático en México y en el mundo.

3. Árboles talados (solo troncos): Al haber árboles talados, menos especies pueden tener donde vivir como las aves, además de que no hay una regulación de la temperatura ambiental y propicia a tener calores más intensos.

4. Árboles sin hojas: Sitios contaminados hacen que la flora y fauna también enfermen y mueran más rápido, lo que propicia un desequilibrio ecológico y biológico.

5. Automóviles: A pesar de ser un medio de transporte muy usado, es contaminante por los gases que emite, y en una ciudad es donde se utilizan más los automóviles, por lo que no es raro que las ciudades esten más contaminadas con respecto a zonas rurales, y se produce un efecto invernadero en el lugar.

6. Conos: Sirven para crear una ambientación citadina y estan relacionados con la generación de tráfico.

6.6. Escenario CubeMap

Se decidio que al desarrollarce la historia de noche el escenario adecuado seria uno que respete la hora, en este caso se agrego estableciendo la ruta de la imagen de cada plano por codigo de la siguiente manera:

```
        // Cubemap
vector<std::string> faces
{
  "bin/textures/cubemap/03/posx.jpg",
  "bin/textures/cubemap/03/negx.jpg",
  "bin/textures/cubemap/03/posy.jpg",
  "bin/textures/cubemap/03/negy.jpg",
  "bin/textures/cubemap/03/posz.jpg",
  "bin/textures/cubemap/03/negz.jpg"
};
mainCubeMap = new CubeMap();
mainCubeMap->loadCubemap(faces);
```

6.7. Audio Files

For the ambiance, two audio files were used: one played continuously to set the atmosphere, and the other played only once at the beginning of the program execution to narrate the scene's context. These audio files are declared as "true"to loop indefinitely or "false"to play them only once.

```
        SoundEngine->play2D("bin/sound/ciudad.mp3", true);
```

```
Sonido2->play2D("bin/sound/narracion.mp3", false);
```

6.8. Lighting Sources

For general purposes, it was desirable in our project to utilize a mobile lighting source, which was implemented using the Phong shader. This lighting source was added to each static model in the scene, specifically within their mathematical data definition, incorporating the same light and material properties for each one in the following manner:

```
        // Configuramos propiedades de fuentes de luz
    phongShader->setVec4("LightColor", light01.Color);
    phongShader->setVec4("LightPower", light01.Power);
    phongShader->setInt("alphaIndex", light01.alphaIndex);
    phongShader->setFloat("distance", light01.distance);
    phongShader->setVec3("lightPosition", light01.Position);
    phongShader->setVec3("lightDirection", light01.Direction);
    phongShader->setVec3("eye", camera.Position);

    // Aplicamos propiedades materiales
    phongShader->setVec4("MaterialAmbientColor", material01.ambient);
    phongShader->setVec4("MaterialDiffuseColor", material01.diffuse);
    phongShader->setVec4("MaterialSpecularColor", material01.specular
       );
    phongShader->setFloat("transparency", material01.transparency);
```

6.9. Programming and Animations

In this project, all animation possibilities were taken into consideration. For instance, in the basic animation, the perpetual movement of a car was considered, which returns to its initial position after reaching a certain distance along the Z-axis. The code for this animation is as follows:

```
      //MOVER CARRO
  if (mov_carro) {
```

```
    if (carro > -1200.0) {
      carro -= 1.0;
    }
    else {
      carro = 0.0;
      mov_carro = false;
    }
  }
```

While in the procedural animation, the movement of the moon was added since our scenario takes place at night. Generally, it is only necessary to create the moon model and add it to the program through the code, but ensuring the appropriate shader is used for procedural animations. The shader for procedural animations is as follows:

```
    proceduralShader->use();
```

And finally, for the keyframe animation, which is used to animate a dirty part with rats, only the rat model variable was created, its poses were calculated, and it was added with the .ºurShader"shader, which is used for animations. The code presented below is used to animate the rats frame by frame so that they can be processed by the program:

```
    // Calculo del framerate de la rata
  currentFrame = (float)glfwGetTime();
  deltaTimeRat = currentFrame - lastFrameRat;
  lastFrameRat = currentFrame;
  elapsedTimeRat += deltaTimeRat;
  if (elapsedTimeRat > 1.0f / fpsRat) {
    animationCountRat++;
    if (animationCountRat > keysRat - 1) {
      animationCountRat = 0;
    }
    // Configuracion de la pose en el instante t
    rat->SetPose((float)animationCountRat, gBonesRat);
    elapsedTimeRat = 0.0f;
  }
```

6.10. Hardware and Software Requirements

In order to use our software, it is important for the user to have a Windows operating system, specifically **Windows 7 or later**, with a **minimum of 2 GB RAM**, an **i3 processor or higher**, and, most importantly, a **graphics card or GPU**, whether it is integrated into the system or an external graphics card. The hardware and software requirements for each team member are as follows:

Nombre	Ferrer Trejo Johan Ariel
Software	Maya 2023
Hardware	Procesador: AMD A10 GPU: AMD RADEON R5 RAM: 8 GB

Figura 2: Requerimientos de Ferrer Trejo Johan Ariel

Nombre	Medina Segura Fernando
Software	Blender 3.5
Hardware	Procesador: 11th Intel Core i5-11400H @ 2.70 GHz 12 CPU´s GPU: NVIDIA GeForce GTX 1650 RAM: 8.00 GB

Figura 3: Requerimientos de Medina Segura Fernando

Nombre	Pérez González Diego
Software	Maya 2024
Hardware	Procesador: Intel Core i5-8300H GPU: NVIDIA GeForce GTX 1050 RAM: 8.00 GB

Figura 4: Requerimientos de Pérez González Diego

Nombre	Recinas Barajas Carlos Eduardo
Software	Blender 3.5
Hardware	Windows 98, Pentium 3 con 256 mb de ram y HDD de 32GB

Figura 5: Requerimientos de Recinas Barajas Carlos Eduardo

Nombre	Zárate García Zuriel
Software	Maya 2022
Hardware	Procesador: Intel Core i5-6200U 2.4GHz GPU: Intel HD Graphics 520 RAM: 12.00 GB

Figura 6: Requerimientos de Zárate García Zuriel

Sign Interaction

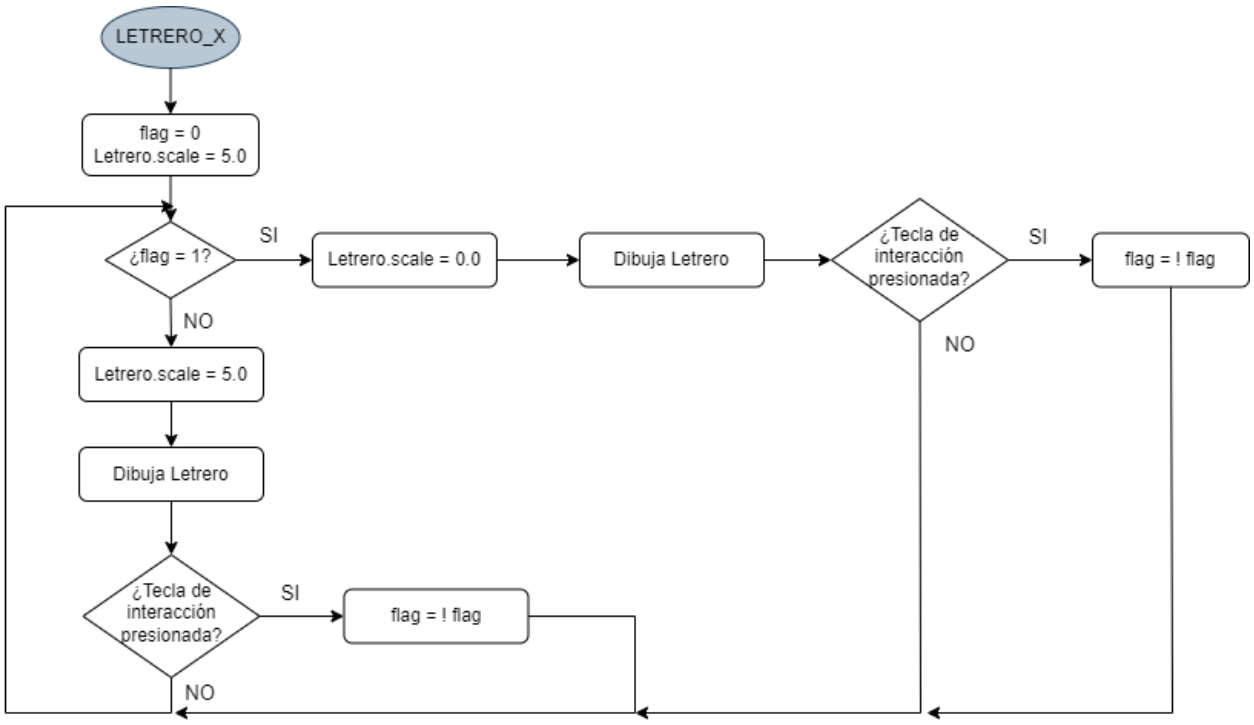

Figura 7: Diagrama de flujo de la interacción con los letreros

Flowcharts

Car animation

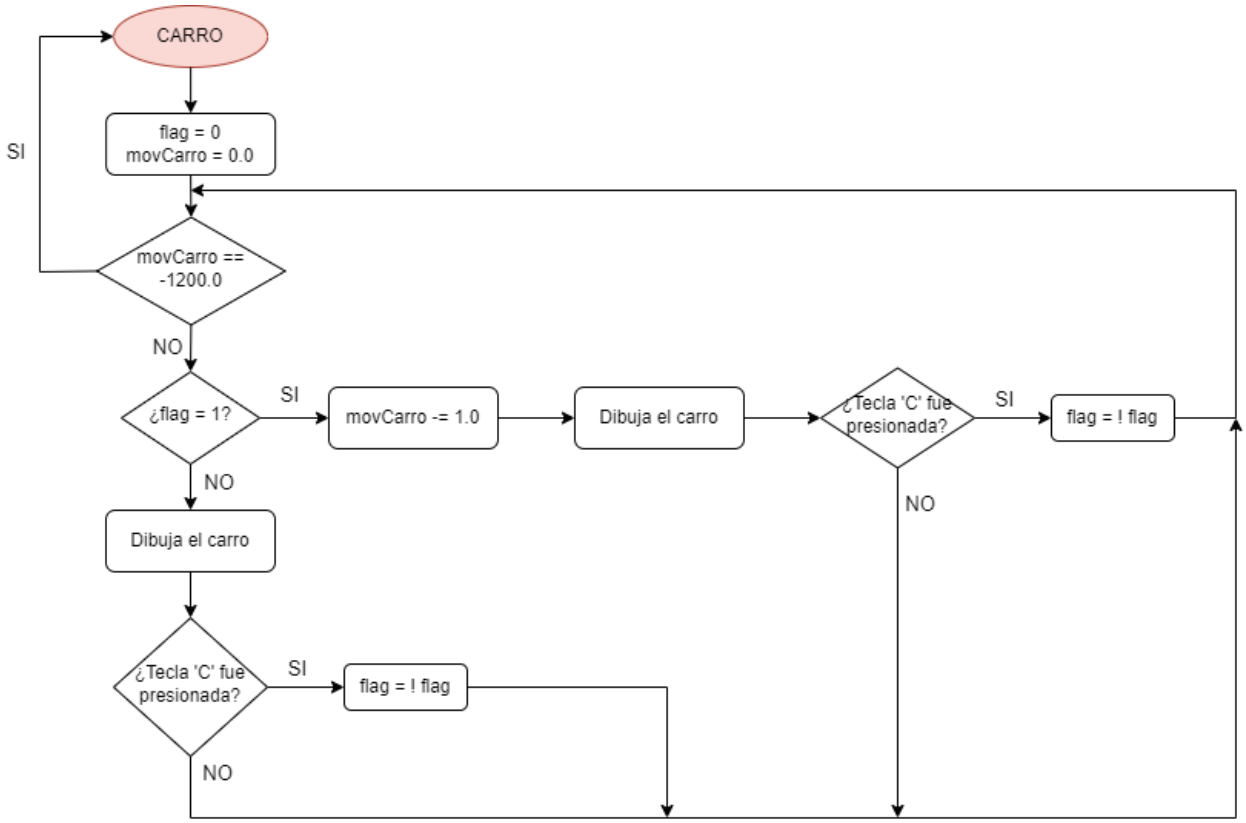

Figura 8: Diagrama de flujo de la animación del carro

6.11. Arquitecturas del programa

Arquitectura general del programa

A grandes rasgos, podemos decir que nuestro programa realiza lo siguiente:

1. Se construyen las primitivas geométricas (puntos, líneas, polígonos, etc).
2. Se posicionan en el espacio 3D
3. Se selecciona el punto de vista
4. Se calcula el color de todos los objetos (según el cómo indice la luz en ellos y según sus texturas).

5. Se dibujan las imágenes conformadas por pixeles.

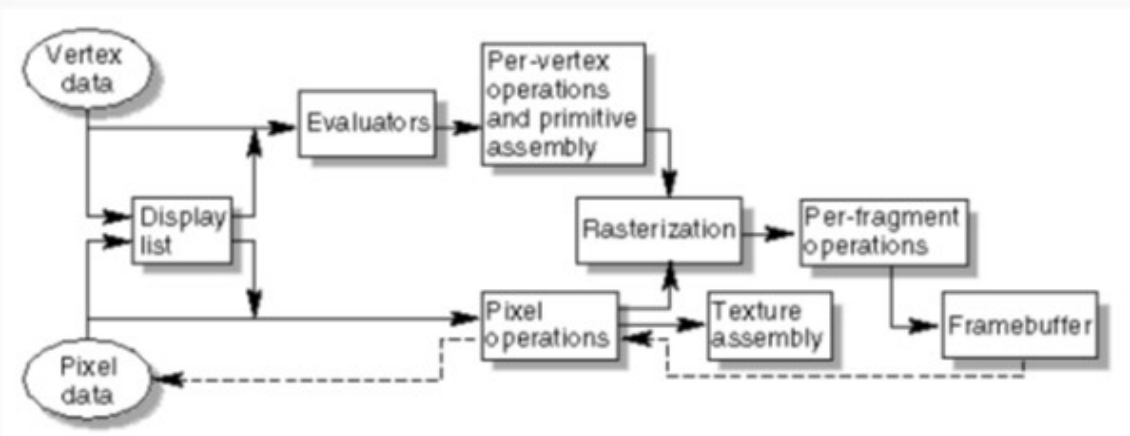

Figura 9: Flujo de un programa escrito en OpenGL

7. Experimentos

7.1. Texturas

En nuestro entregable anterior, implementamos ciertas texturas para intentar ambientar al usuario en un espacio mexicano cotidiano, por lo que modelamos tiendas y tortillerías. Aunque esto resultaba bien, tuvimos que modificar las texturas de este tipo de objetos para evitar el uso de marcas comerciales. A continuación se muestran algunos ejemplos.

Figura 10: Primera versión de tienda

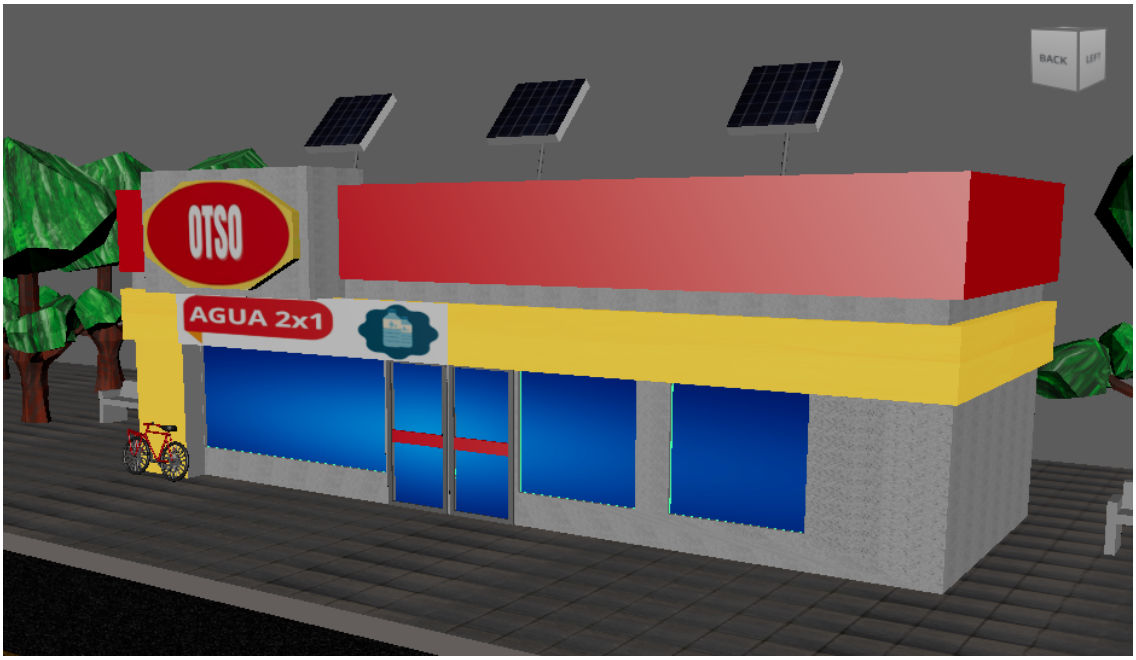

Figura 11: Versión final de tienda

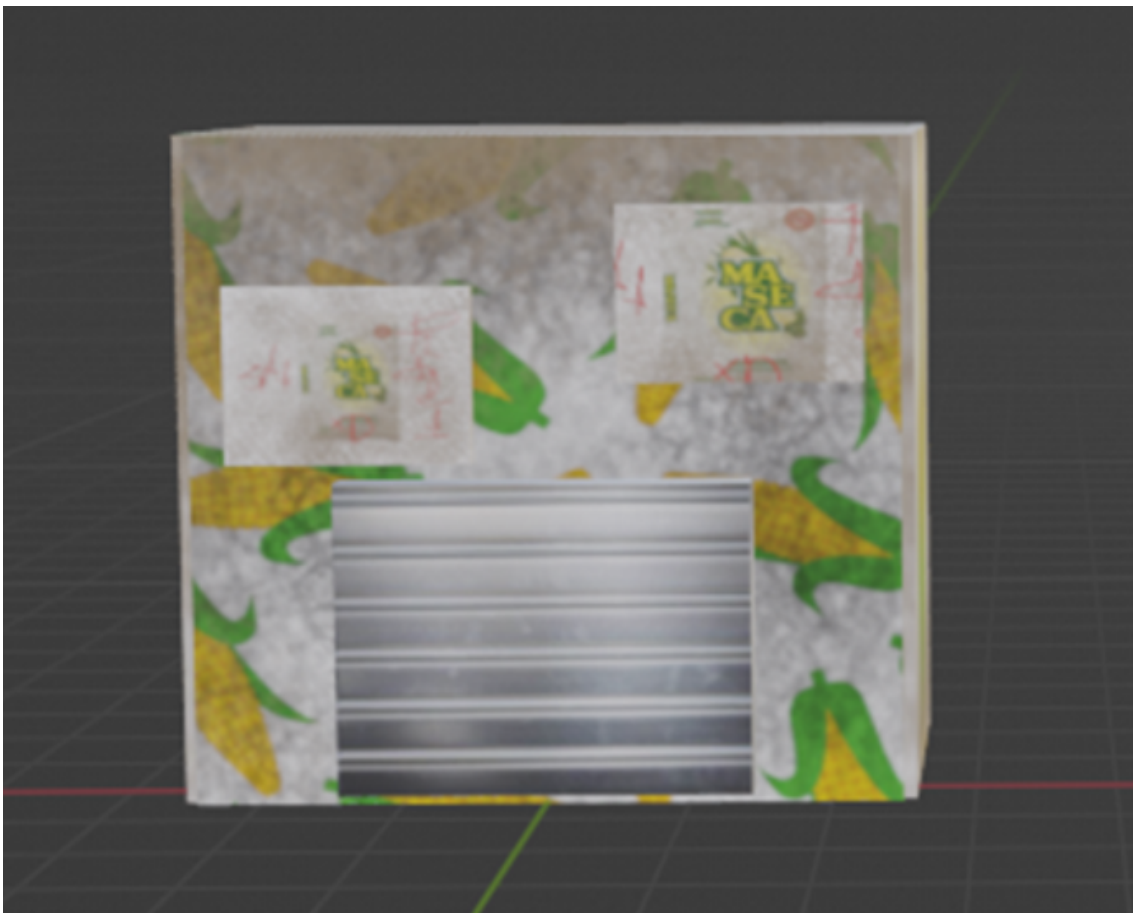

Figura 12: Primera versión de tortilleria

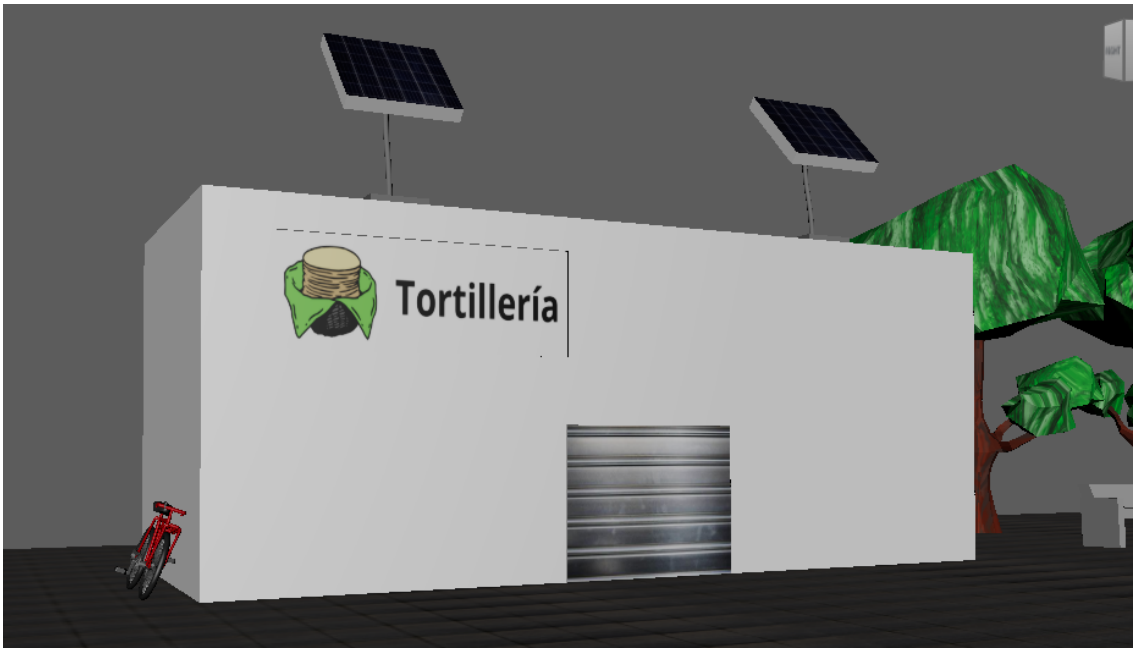

Figura 13: Versión final de tortilleria

Además, mejoramos las texturas del escenario en general, ya que, en nuestro primer intento, las texturas no se veían lo suficientemente reales para envolver al usuario en la experiencia.

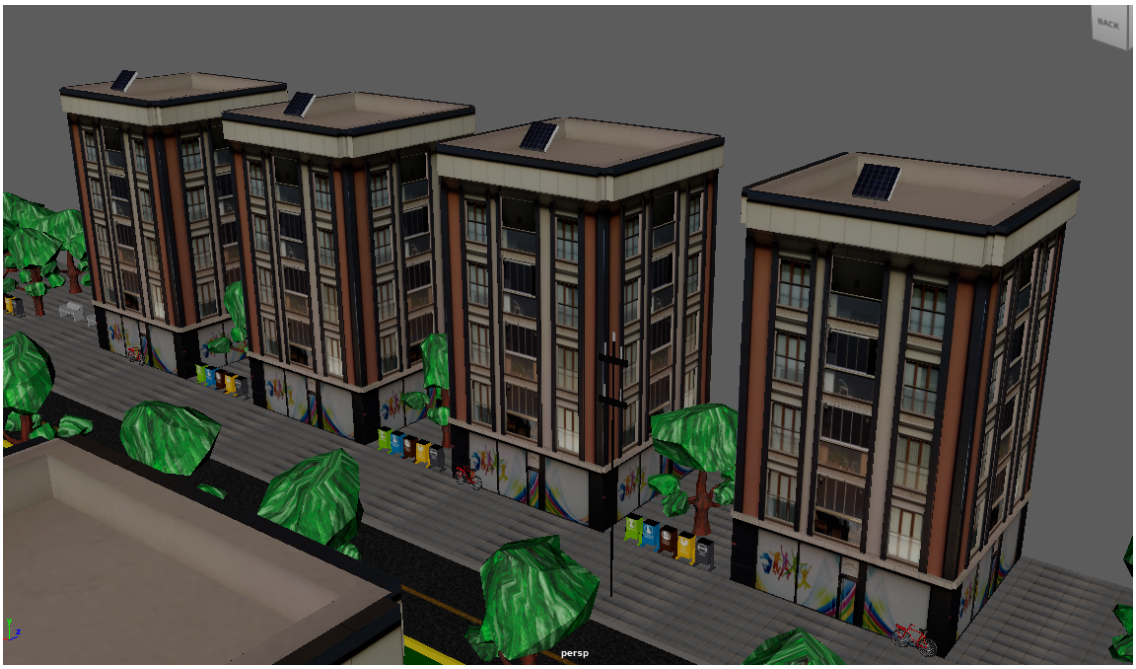

Figura 14: Vista general del mejorado de texturas y ambientación.

7.2. Animaciones

En cuanto a nuestras animaciones, teníamos la intención de tener dos animaciones procedurales. Una que reflejara la contaminación en el agua y otra que mostrara el movimiento natural de la luna.

En cuanto a la animación de la luna, lo único que cambiamos fue el tamaño de la luna, la distancia entre la luna y el centro de rotación y la velocidad de su movimiento, ya que, en primeros experimentos, vimos que la luna se veía demasiado grande y avanzaba muy rápido, pero funcionaba bien para crear un ambiente nocturno, que era lo que queríamos con la iluminación y el *SkyBox* elegido.

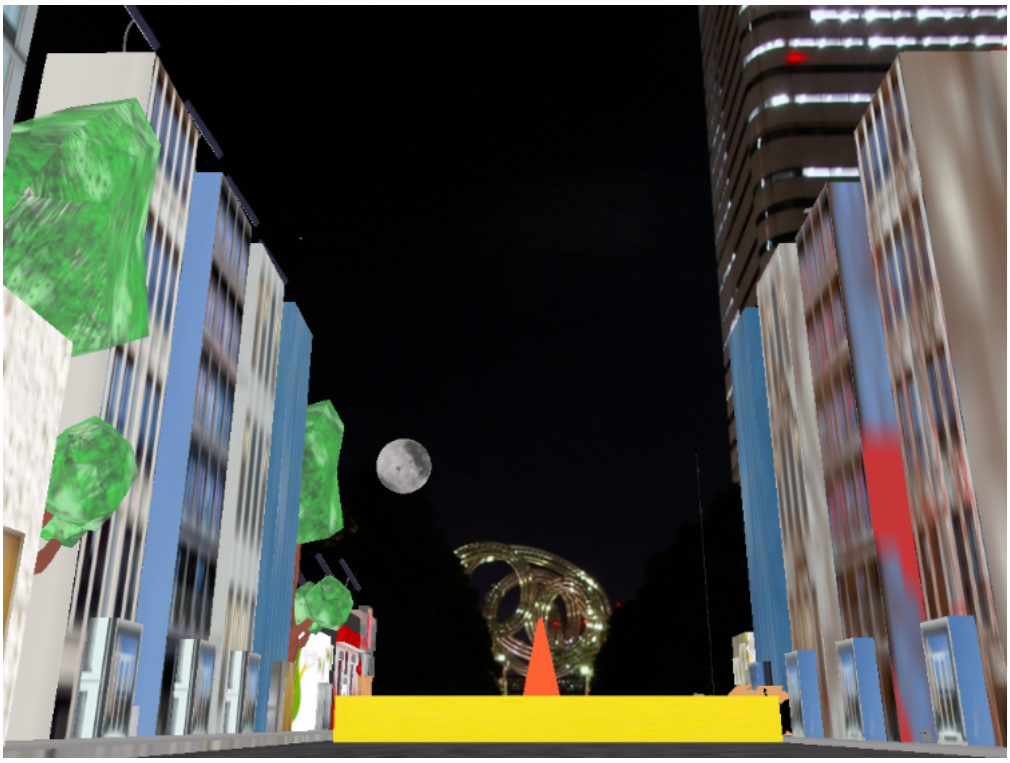

Figura 15: Animación de la luna 1

Figura 16: Animación de la luna 2

Por otra parte, nuestra animación de agua fue descartada debido a que no encajaba, como imaginamos inicialmente, ya que la textura no era correcta y el plano del agua no podíamos situarlo tan fácilmente en nuestro escenario. Además, el reflejo de la textura seleccionada no coincidía con nuestra ambientación nocturna, por lo que preferimos remover esta animación.

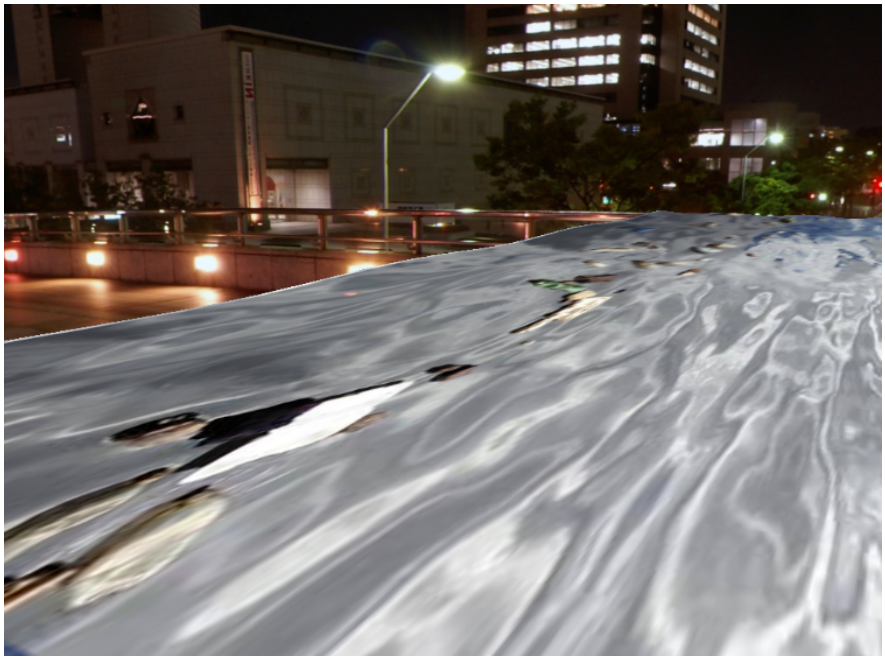

Figura 17: Animación de agua

También, tenemos 2 experimentos más que funcionaron bien. Ambos son modelos animados por *keyframes*, uno de ellos es una rata (la cual cuatriplicamos para dar la sensación de las plagas citadinas) y un personaje que camina en el escenario y que sirve como expectador. Para poder lograr esto, tuvimos que hacer dos shaders: "ourShader" y "ratShader", para poder recorrer los cuadros clave del personaje y las ratas respectivamente.

Por un lado, las ratas son dibujadas y sufren transformaciones de traslación, programadas de manera diferente por cada rata dibujada. Por otro lado, el personaje se traslada según lo que decida el usuario con las interacciones especificadas en el manual de usuario. Ambos experimentos resultaron funcionar muy bien y los dejamos en el entregable final.

Figura 18: Modelo del personaje

Figura 19: Modelo de la rata

7.3. Entorno

El entorno lucía muy diferente como lo teníamos en nuestra primera entrega a como luce en esta entrega final. A continuación se mostrarán las imagenes de ambos entornos.

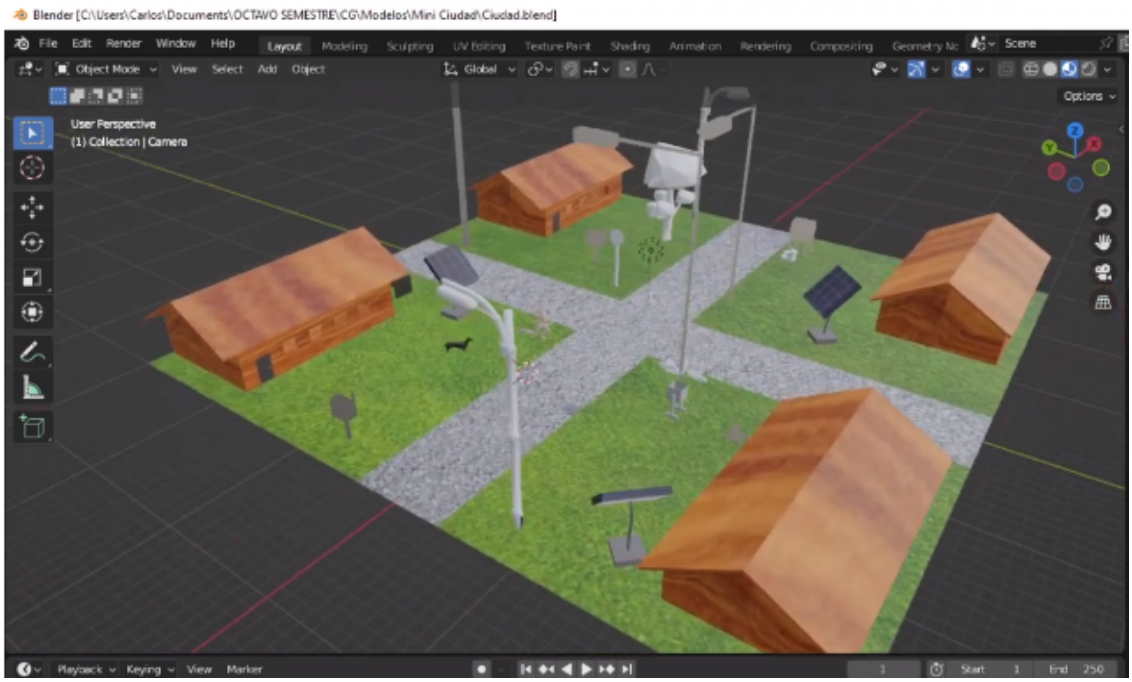

Figura 20: Vista general del primer escenario.

Figura 21: Vista general del segundo escenario.

7.4. Uso inadecuado de shader

Al cambiar el shader usado para una animación en específico suele suceder que no se anime como se esperaba, aunque la mayoría de las veces compite sin errores. Por ejemplo, cuando se cambia nuestro shader por el estático en una animación por keyframes obtenemos que el personaje pierde toda su animación.

Figura 22: Carga de personaje

7.5. Cambio de ruta de modelo

Al cambiar la ruta asociada al modelo en el código suele provocar que en muchas ocasiones el programa compile pero que desde la terminal se notifique que no encontró el archivo en esa ruta y podría llegar a detenerse la ejecución del programa. En este caso si cambiamos la ruta del personaje la librería de assimp no tolera el no encontrar el archivo dando por finalizada la ejecución del mismo.

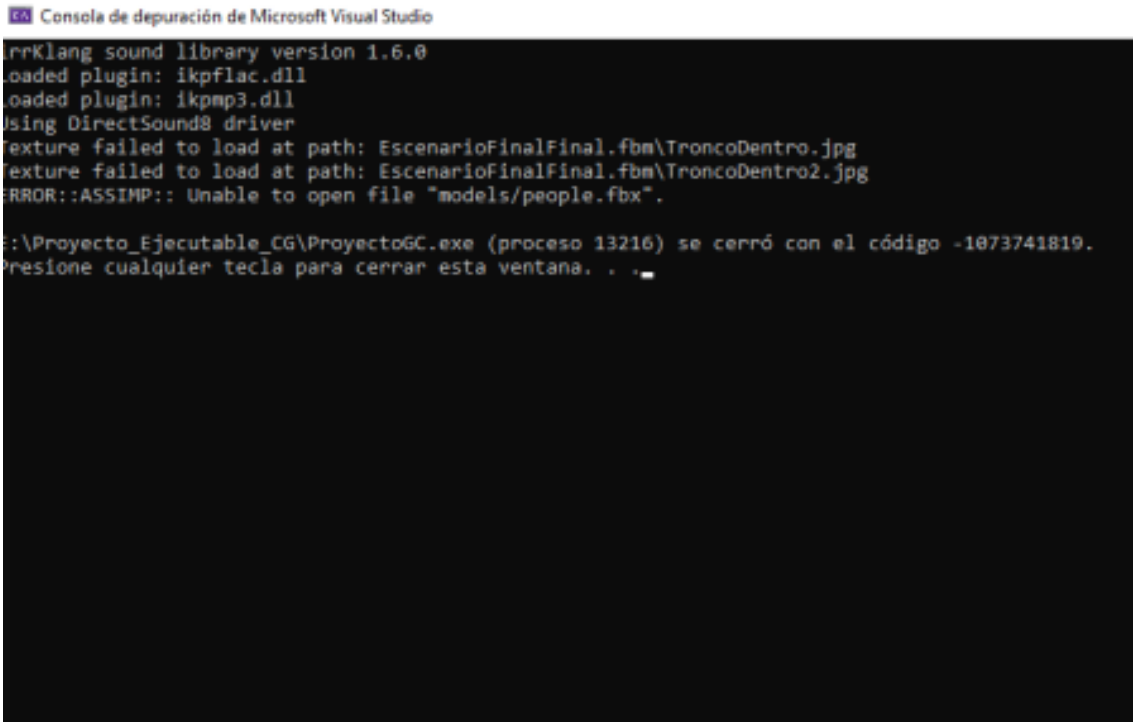

Figura 23: Error en carga

7.6. Cambio de ruta del shader

When changing the shader path in each case the program compiles but runs without the model to load, while in the terminal it warns that the arrays that generate it do not exist. while in the terminal it warns that the arrays that generate it do not exist.

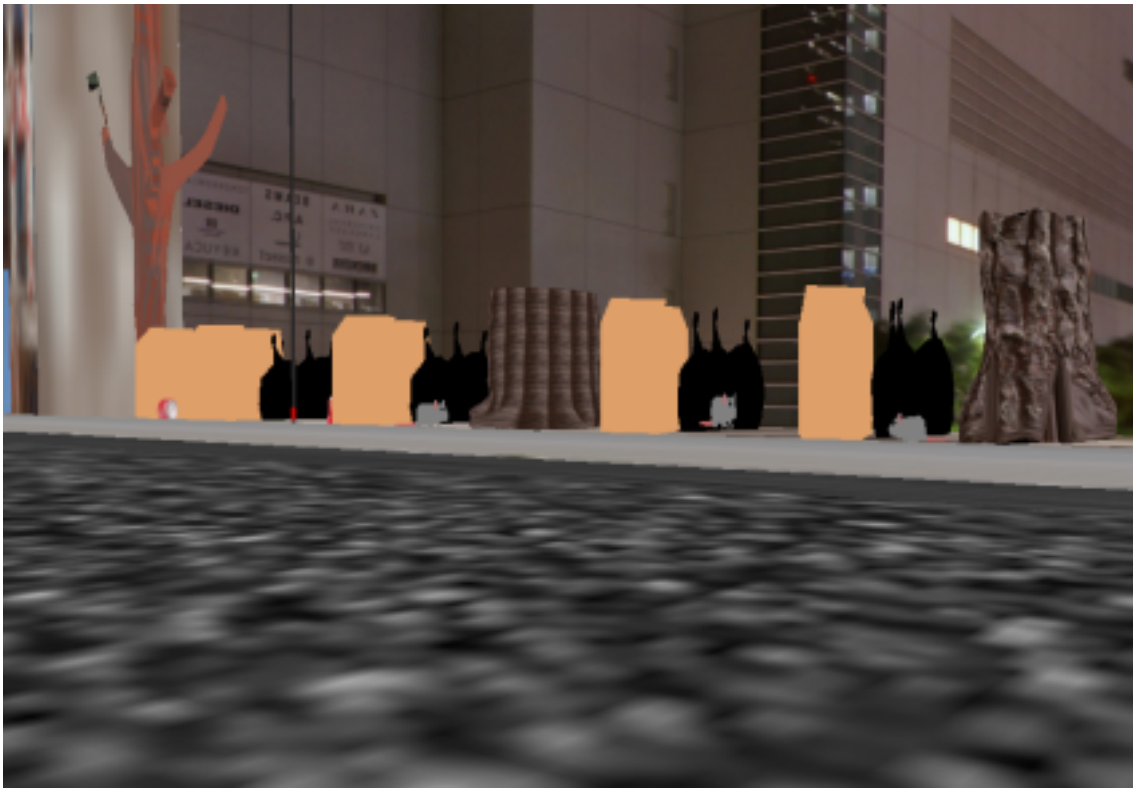

Figura 24: Shader effect without path

7.7. Cubemap route change

When the cubemap is altered in only one of its faces it will not load even if it is only one of the faces with the error. the one with the error, the program will compile and run but without the background view caused by the cube map. the cube map.

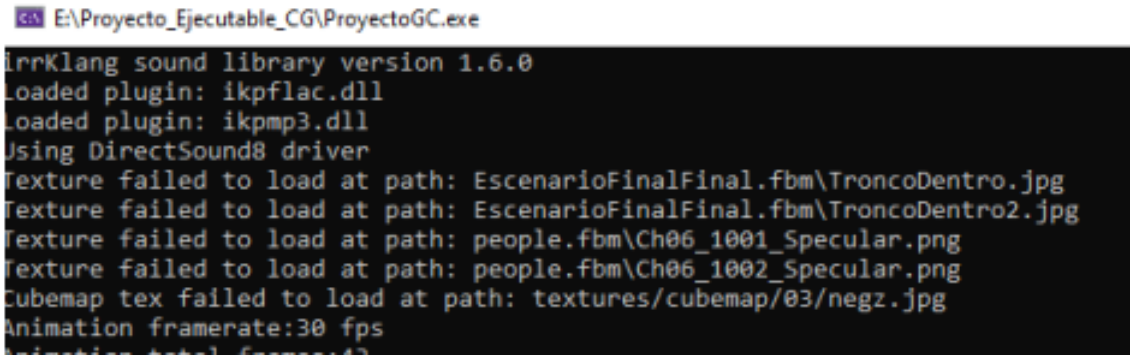

Figura 25: Cubemap loading errors

7.8. Storyreel

In this final installment, the idea is that the user can contemplate a scenario in which the different objects are located in strategic positions, in this way, we propose that, when the tour starts, he can freely explore the street and at the same time he can observe his surroundings and analyze the situation. He can also do it from the perspective of a character that is in our environment, which the user can manipulate as he wishes. Our scenario aims to show the difference between a place with pollution and another in which the state of the environment is more careful, and thus, we can denote that by performing certain actions can have positive changes or changes that have negative consequences, depending on what is done by humans, particularly talking about pollution. There are signs that tell us how to interact with the environment, others that will give us relevant information about pollution and others that will be instructions for the user. As well as the signs there are some interactions such as the movement of a vehicle and one that helps to change the lighting of the environment.

8. Results

Based on the multiple experiments carried out throughout the semester, we were adapting our project until we reached a point in which this work met what we had proposed at the beginning of the semester in our objectives. The final results are as fo

When we start the tour inside our virtual environment, we can notice that on the sides we have two streets. However, if we look closely we will notice that both are the same street, we can see that the one on the right side has been affected by climate change, while the one on the left side was taken into account the care of the environment. Based on this, the user will be able to investigate around our environment where he will find multiple interactions, informative data and elements that accompany the environment in order to make the user reflect and act for the benefit of environmental care.

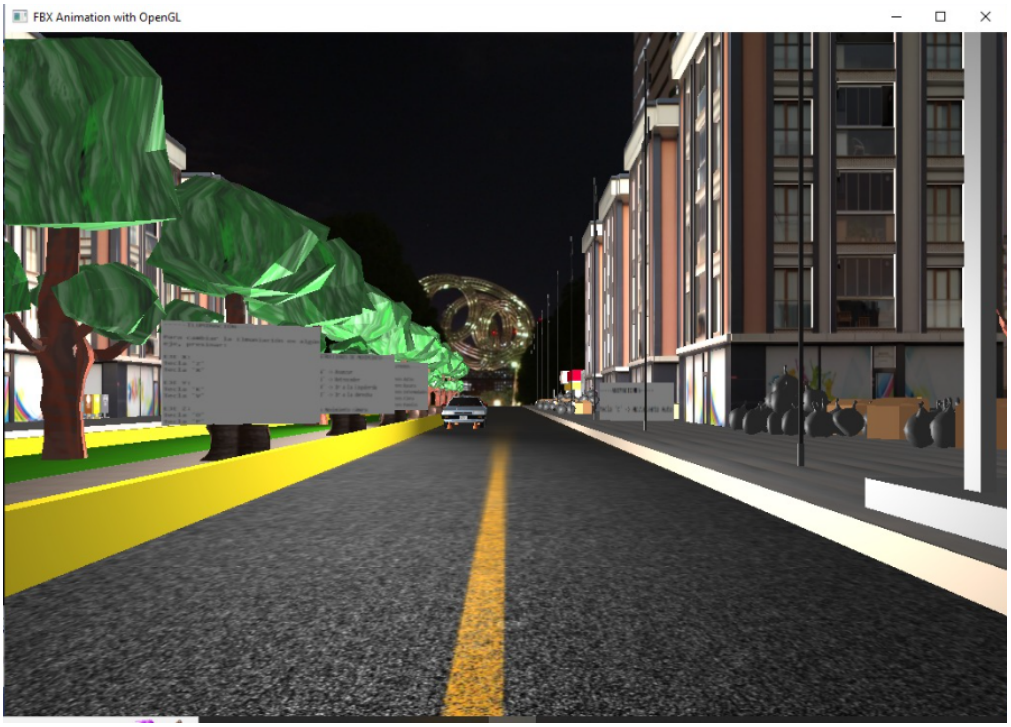

Figura 26: Camera start

Likewise, when the tour starts, we will be able to see several signs that serve as a user's guide. In these signs, it is clearly indicated how the executable of our project should be used. Once you start to move through our virtual environment, you can also view and interact with more posters, these will provide relevant information and some suggestions at strategic points, emphasizing the situation that is being simulated, ie, the effects of climate change in Mexico.

On the polluted side, we will find certain elements that help us to represent how much environmental pollution can affect us if we do not do something to stop it. We can see stores without merchandise, trees cut down, dry grass, garbage everywhere, pests in the street, etc. All this is complemented by the information provided in the posters already mentioned.

On this same side, we can find a pair of automobiles, one broken down and another one that circulates on the street. The second has an interaction which shows us the route of the vehicle, this interaction has two posters (mentioned above), one tells us how much pollutes a car and the ecological alternative that can be used as transportation, and the other serves for the user to interact with the vehicle.

On the side where there is environmental awareness, we can find multiple elements that

help to complement the idea of a more ecological culture. Some of these elements refer to sustainability, sustainability, environmental responsibility, and so on. For example, you can see that solar panels are used on the roofs of the structures, which is accompanied by a sign that talks about the benefits they provide.

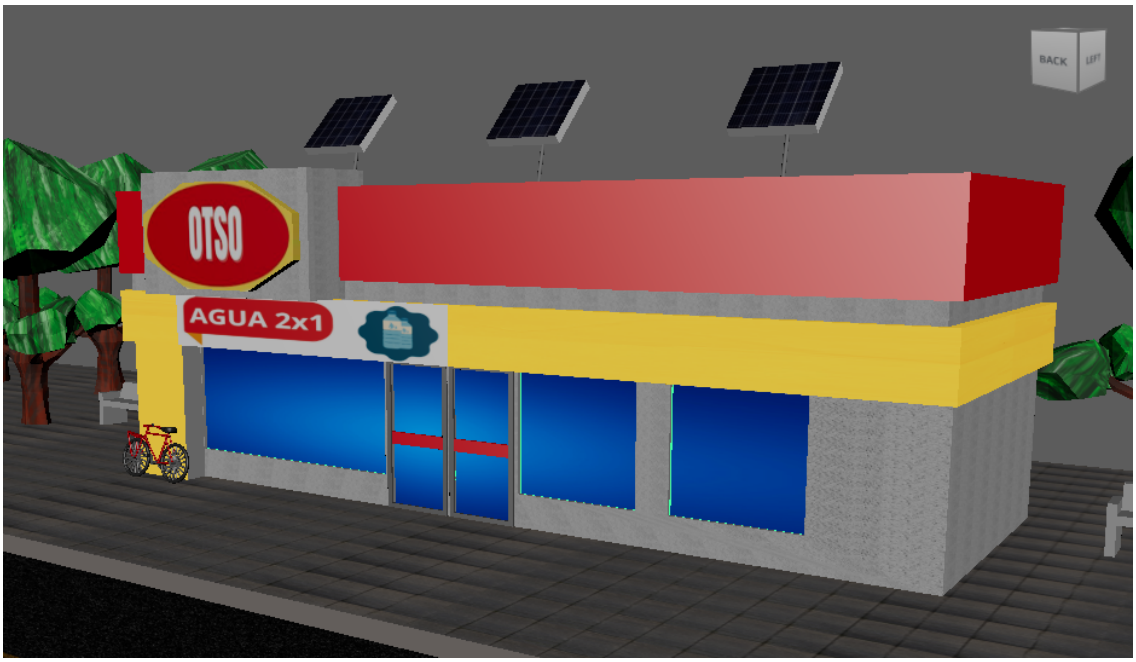

Figura 27: Solar panels on structures

Continuing with this side of the viral environment, the flora is also in an ideal state, that is to say, the trees are not cut down and the grass has its usual color. In addition, in the structures that refer to the self-service stores, it can be seen that they are not affected by possible shortages. There are also bicycles that encourage the use of bicycles instead of cars.

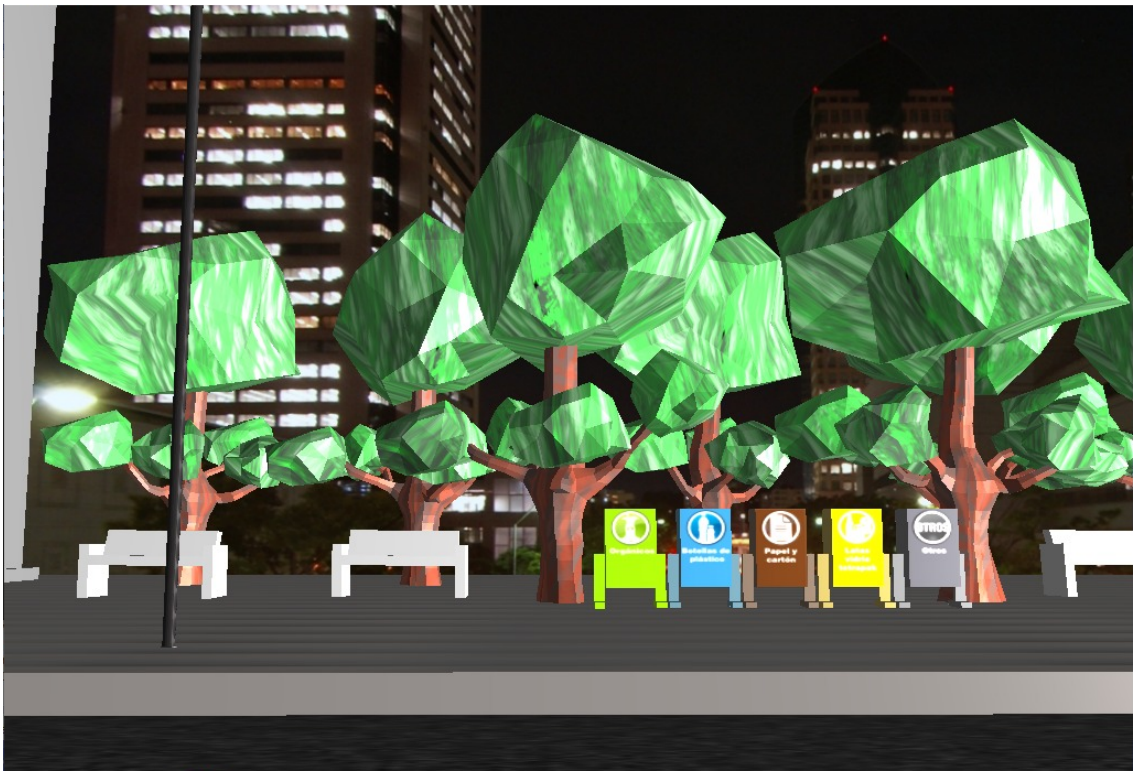

Figura 28: Trees in good condition

As a complement to our virtual environment and in order to enrich our simulation, we used a procedural animation that simulates the translation movement of the moon. Mathematical calculations were used for this animation to make the result as realistic as possible.

Another animation that can be found is the one found in a character that we add, with which you can also interact, since, with a certain key (specified on a sign) we can put the camera in third person with respect to the character, and not only that, we can move this by our environment giving a touch of realism to our work, allowing the user to choose how you want to move with the character (third person) or if only with the camera (first person).

Figura 29: Third-person camera

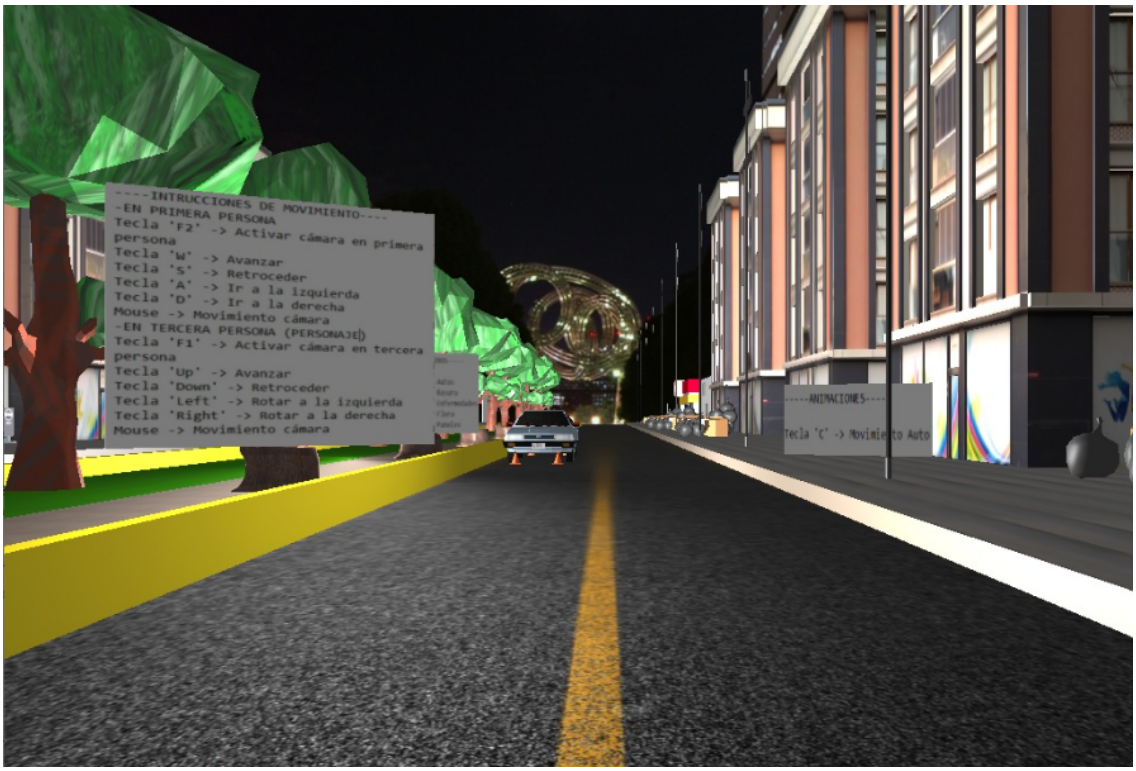

Figura 30: First-person camera

Another point to highlight is the ability to vary the illumination of the environment on the desired axis. The user will be able to press some keys that are specified in a sign.

Advantages and disadvantages of the applied methodology

By using the SCRUM methodology we obtained certain advantages that allowed us to have great progress in our project. One of these advantages is adaptability, thanks to this, the iterations we made were short, which allowed us to adapt quickly to changes and emerging requirements as we progressed with the project.

On the other hand, it also gave us greater transparency when making changes at different stages of the project. This was possible because all team members had visibility on the progress, tasks, pending tasks, etcetera. Allowing us to have greater communication and collaboration.

One of the advantages we gained from having to constantly comply with each sprint was that this provided us with early feedback so that we could make adjustments as needed. Finally, one of the most important and most beneficial points was that we gave a value approach to some developments, i.e., we prioritized the most important features and functionalities.

However, there were also certain disadvantages that presented us with different difficulties at the time of working. One of them is the difficulty to estimate the time, this is due to the fact that we work with short iterations with frequent changes, causing us to be somewhat complex to accurately estimate the duration of some sprints, resulting in difficulties for the planning and management of the project.

Another disadvantage was that having to work with rapid advances, this generated some problems at the time of understanding the stage that was being worked on, either in terms of code or when working with the scenario. Finally, since this methodology is based on self-organized and multifunctional teams, it created conflict with the different training, availability, motivation and other aspects presented by each team member.

Comparison with other existing developments

In order to see how efficient our project is, what it lacks and where it gets it right, we will compare it with some existing climate change awareness software.

We will start by mentioning the online software "Global Forest Watch", which uses ad-

vanced technology to monitor and protect forests around the world. Its main objective is to provide up-to-date and detailed information on the health of forests and the changes occurring in them globally.

To achieve this, GFW collects and analyzes data from a variety of sources, including satellite imagery, government reports, non-governmental organizations and local communities. This provides a complete picture of the state of the world's forests. Using advanced image processing and machine learning algorithms, GFW can identify deforestation, forest degradation and other changes in forest cover.

Another software visited was Çool Farm Tool", which is primarily aimed at helping farmers and food producers assess and manage greenhouse gas (GHG) emissions and other environmental impacts of their farming operations.

This is based on a recognized scientific methodology and uses research data to calculate GHG emissions at different stages of agricultural production, including crop production, livestock and waste management. It also takes into account other environmental impacts, such as water use and biodiversity loss.

By carrying out a comparison with the aforementioned software, we can notice that our project has limitations in terms of the information presented in certain posters, which, although they are from official sources and related to the subject, they are general because they are intended for any type of person to be able to quickly relate it to the reality they are living. In addition, such information is not constantly updated as in one of the software visited, which would help to create a closer awareness of the problem that is being experienced.

8.1. Methodology results

Results of cubemap: The implemented cubemap can be viewed properly without any kind of problem:

Figura 31: Cubemap scenario

Lighting source results: As the source is mobile, it can be visualized anywhere and can illuminate the objects to a greater or lesser extent:

Figura 32: Phong Model

Basic Animation Results: The basic animation related to the movement of the car is correctly performed by pressing the ç"key:

Figura 33: Basic animation

Results of procedural animation: The procedural animation is applied to the moon at a certain distance from the stage:

Figura 34: Procedural moon

Keyframe animation results: Keyframe animation is applied to the movement of the rats:

Figura 35: Rat for keyframes

8.2. Experiment results

Figura 36: Scenario vector loading

Figura 37: Addition of character with animation

Figura 38: Stage moon

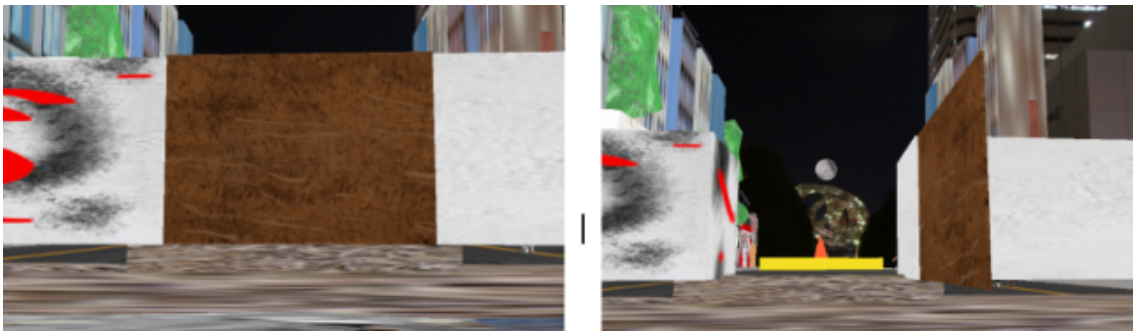

Figura 39: Door that opens and closes

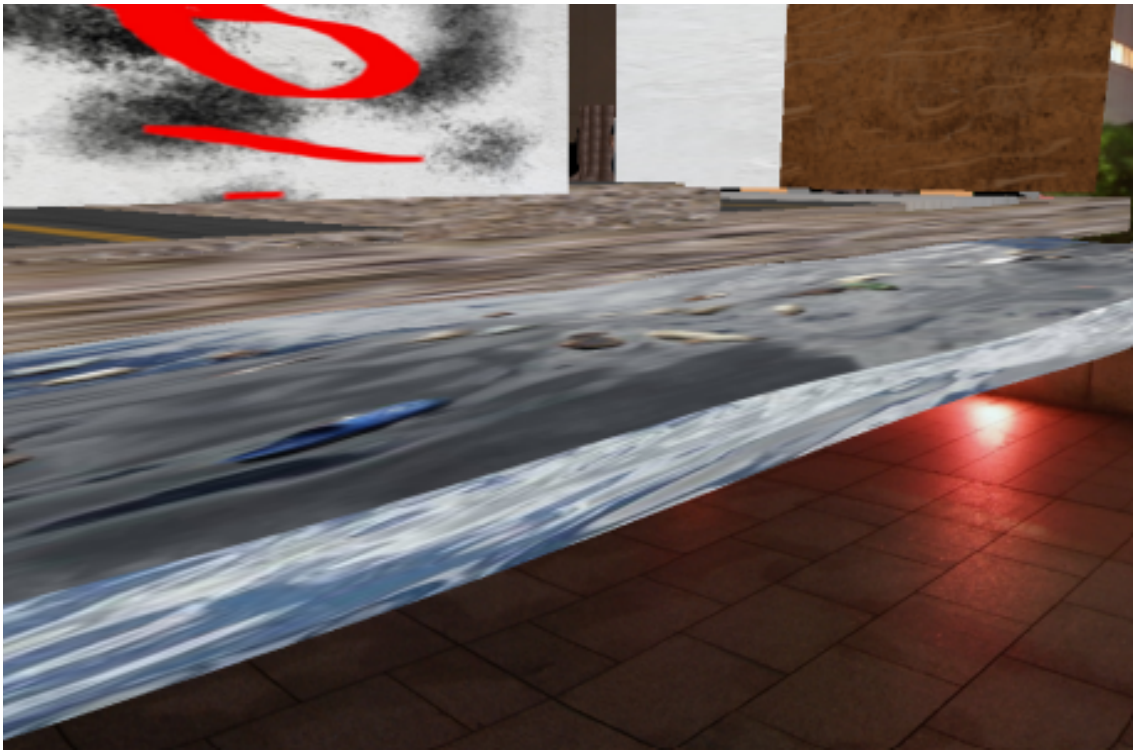

Figura 40: Dirty water

Figura 41: Cubemap city

8.3. Improper use of the shader

To solve this problem it is necessary to have knowledge to a certain degree of the use associated to each shader used. associated to each shader used, in this case as its name says, the staticShader is for static objects and ourShader is for character animation. static objects and ourShader is for character animation, so the most appropriate should be to use ourShader in this situation. should be to use ourShader in this situation.

Figura 42: Character shader

8.4. Model route change

To solve this problem you must identify the path to the model file and assign it with its extension to the file for further processing. even with its extension to the file for further processing. In this case, it already loads properly.

Figura 43: Adequate model load

8.5. Shader path change

To solve this issue you must identify the part where the shader was defined and see if the path both .fs and .vs are correct. .fs .vs path are the correct ones, if they are not they should be changed. the program compiles and executes but the shapes are not seen.

```
// Compilación y enlace de shaders
ourShader = new Shader("bin/shaders/10_vertex_skinning-IT.vs", "bin/shaders/10_fragment_skinning-IT.fs");
cubemapShader = new Shader("bin/shaders/10_vertex_cubemap.vs", "bin/shaders/10_fragment_cubemap.fs");
particlesShader = new Shader("bin/shaders/13_particles.vs", "bin/shaders/13_particles.fs");
staticShader = new Shader("bin/shaders/10_vertex_simple.vs", "bin/shaders/10_fragment_simple.fs");//Para objetos estaticos
wavesShader = new Shader("bin/shaders/13_wavesAnimation.vs", "bin/shaders/13_wavesAnimation.fs");//Para el agua
proceduralShader = new Shader("bin/shaders/12_ProceduralAnimation.vs", "bin/shaders/12_ProceduralAnimation.fs");
mLightsShader = new Shader("bin/shaders/11_PhongShaderMultLights.vs", "bin/shaders/11_PhongShaderMultLights.fs");
```

Figura 44: Shader paths

8.6. Cubemap route change

Para este problema al ser 6 direcciónes a considerar, previamente se recomienda tenerlas todas en la misma carpeta y al identificar cual es esta se debe de incluir su ruta de c/u en el código, de la siguiente manera:

```
// Compilación y enlace de shaders
ourShader = new Shader("bin/shaders/10_vertex_skinning-IT.vs", "bin/shaders/10_fragment_skinning-IT.fs");
cubemapShader = new Shader("bin/shaders/10_vertex_cubemap.vs", "bin/shaders/10_fragment_cubemap.fs");
particlesShader = new Shader("bin/shaders/13_particles.vs", "bin/shaders/13_particles.fs");
staticShader = new Shader("bin/shaders/10_vertex_simple.vs", "bin/shaders/10_fragment_simple.fs");//Para objetos estaticos
wavesShader = new Shader("bin/shaders/13_wavesAnimation.vs", "bin/shaders/13_wavesAnimation.fs");//Para el agua
proceduralShader = new Shader("bin/shaders/12_ProceduralAnimation.vs", "bin/shaders/12_ProceduralAnimation.fs");
mLightsShader = new Shader("bin/shaders/11_PhongShaderMultLights.vs", "bin/shaders/11_PhongShaderMultLights.fs");
```

Figura 45: cubemap code

Once the correct routes have been set, the program is executed, since a single failure of these will not be seen in the execution, that is why it is important to consider using the correct routes. will not be seen in the execution, that is why it is important to consider using the right paths.

9. Conclusions

Ferrer Trejo Johan Ariel (317008230)

The final delivery of this project is the culmination of the work done throughout the semester. Undoubtedly, it is one of the is one of the works to which I have dedicated more time because of the amount of concepts, tools and applications that can be used in the field of computer graphics, tools and applications that can be used in the field of computer graphics. The The subject demands previous knowledge and a clear understanding of the new knowledge that it gives us, which adds some complexity at the time of applying this knowledge in the development of this work. But thanks to both theory and laboratory classes, I was able to understand the best way to apply what I learned, both in the modeling software, particularly Maya, which was the one I used, and in the software for code development, in this case OpenGL with a C++ extension. The project simulates the effects of climate change in Mexico, which represented a very interesting challenge for the items that we had to meet to reach the initial goal. Working with this topic involved extensive research on the causes,

consequences and possible solutions to climate change, on the other hand, giving the approach we wanted so that anyone can understand the message and apply it to their daily lives, also involved a lot of work by the whole team to focus on the main causes of environmental degradation. However, I consider that despite the difficulties presented, we managed to carry out the planned project, which meets the expectations we had. The application of modeling, texturing, animation, lighting, etc., was quite simple thanks to the methodology used, this methodology allowed us to make a good teamwork and I think it is reflected in this report. Finally, it only remains for me to highlight the importance and depth that can have the area of computer graphics, taking it to have no limitations for the creation of what you want.

Medina Segura Fernando (317174948)

In the development of this final project was a great burden but in turn was something interesting to create, from the beginning of the semester to the final delivery, following the steps of the graphic pipeline and SCRUM methodology, it was possible to address in a good way the development of the project, from conceptualization, where we had several ideas but in the end we opted for a mirror mode scenario; We went through the modeling in modeling software such as Blender and Maya, learning to texture and create translucent materials, and in OpenGL to put the lighting through the Phong shader, and basic animations (posters), procedural (moon and car) and keyframes (character and rats); but undoubtedly the most important thing of the project was, besides implementing all the theoretical and practical knowledge seen in class, is that you can create a virtual environment that has an application in real life, through, in our case, give a message to the user who uses our software about the awareness of environmental care to avoid serious consequences on our planet as is the climate change, and the fact that the project was done as a team enriched the creation of the project, because everyone had ideas and points of view, and agreeing on what to do and how to do it is what culminated in a good way in the creation of the virtual environment, and also put into practice knowledge of past subjects of programming and software engineering to understand how to develop projects in the workplace.

Pérez González Diego (317160349)

In this project, I had the opportunity to apply my knowledge on the subject and work together with my team in an investigation on a crucial issue that concerns us all: environmental pollution. Our main objective was to create an environment that would raise awareness about the importance of caring for the environment and the worrying issue of climate change. To achieve this, we used models both created by us and obtained from the Internet, we textured the objects, we gave them lighting and some of them even had animations and interactions with the user.

Despite facing complications in terms of models, animations, code, among other aspects, we were able to complete our work fulfilling the initial objectives. Throughout the creation process, the project underwent numerous changes, but I consider that they were all positive. This was largely due to the elements we learned in the subject of Software Engineering, as they allowed us to create projects effectively. That is why I consider both the realization of the OpenGL environment and the documentation of it as fundamental aspects, as one cannot work without the other.

Finally, this project was unique and excellently executed. It felt different because, before tackling any computer engineering aspect, we had to come up with a solution to an important social problem and, based on that solution, research and familiarize ourselves with the topic. I think it was this combination of the social solution and the technical aspects that made the project stand out.

Recinas Barajas Carlos Eduardo (317335291)

In this project I managed to better understand how to implement the various things learned in the course in a single openGL code, from simple things like importing shapes to the creation of characters, lighting models and particle generation. The application of the correct shaders is also one of the learning axes acquired in the course and which facilitated the development of the course, also the practices and codes developed in past sessions certainly helped greatly.

Zárate García Zuriel (315270288)

This project turned out to be quite an interesting challenge for me, as it integrates parts that involve other subjects, such as *Software Engineering* (Documentation needed for the software life cycle), *Software Project Management* (Process management, communication, requirements analysis, resource management etc), *Object Oriented Programming* (since C++ has the advantage of handling classes and objects, which we use in our programs and Shaders)*Data Structures and Algorithms* (Arrays, pointer management, etc), *Linear Algebra* (operations with transformation matrices), *Mechanics* (for specific animations), among others. In addition, the workload turned out to be the highest I have had so far, so working in a relatively large team was beneficial in the end.

In my opinion, the biggest challenge we had to face as a team was communication and development management, as we fell several times into breaking agreements and making unilateral decisions. However, after several meetings to discuss our areas of opportunity, we were able to carry out the development in an agile and more bearable way.

At the end of all this, the knowledge I acquired was much more than I expected and I realize that this branch of computing is too extensive by the number of disciplines that can be integrated, so it is not an easy task and, I think, it is not convenient that jobs like this are done individually, the larger the team, the better, although in terms of administration is a greater challenge.

On the other hand, it seems to me that we fulfilled the objectives of our project very well, since the final result, in effect, reflects the negative effects of climate change in our country and provides alternatives that can be followed to curb this disaster that is nipping at our heels more and more every day. The final scenario is immersive to the eye and ear, since our textures are realistic, our lighting provides depth and we were able to implement ambient sound in the program. In addition, the natural movement provided by the keyframe animation makes the environment richer.

That is why I am very happy and satisfied with our final results and I hope that this work really impacts the senses of those who experiment with it.

10. Link to video

https://drive.google.com/file/d/1oAV8ODUopYpVXDHnrVlrXirXz9w--JKT/view?usp=sharing

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