Interactive Graphics
Final Course Project

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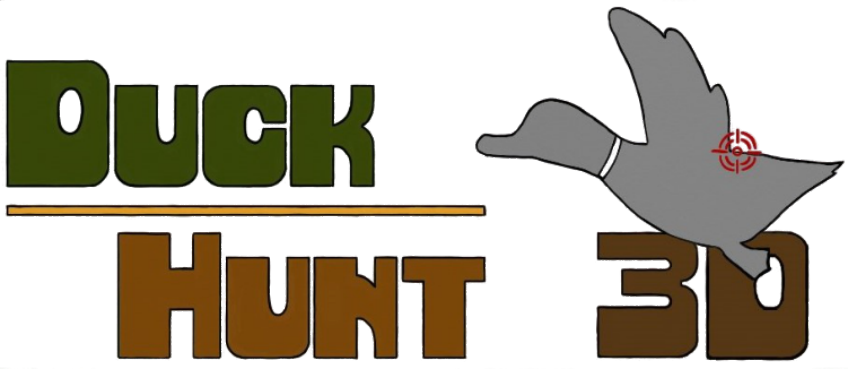

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1 Introduction

The goal of the project is to implement an interactive application that makes use of basic WebGL or advanced libraries, as in our case ThreeJS. The project cover the main aspects treated during the course, such as lights, textures, hierarchical models and animations.

2 Game

We decided to develop a 3D version of "Duck Hunt", a famous game from the 80s, in which the objective is to hit as many ducks as possible. We designed the scene as a first-person game, where the player is located in a tall grass field and controls a rifle. Thanks to the help of his dog, that frighten the ducks hidden in the tall grass, the hunt can start. The game ends when the player miss five ducks. In addition, our game provides other functionalities like enable and disable sounds, pause the game or restart it.

The above described scene is depicted in the following figure:

Figure 1: Starting scene of the game.

3 Scene

The scene shown in Figure 1, which is a ThreeJS object, has been obtained adding textures, lights, and different 3D models. The dog and the ducks are hand-made models while the other are taken from SketchFab. We used perspective camera to make the scene as realistic as possible to let the center of projection coincide with the user's eyes. The prospective uses as parameters: *fovy, aspect, near and far*. *Fovy*, which stands for "field of view y-axis", identifies how wide the eyes open along the y direction. *Aspect* represent the ratio between the width and height of the canvas. *Near* and *far* are any positive numbers representing the minimum and maximum distances of the object, with the restriction that near is always less than far. For the camera is defined also the *lookAt(x, y, z)* method, where the x, y and z are the coordinates of the scene. The texts on the bottom

right corner instead, have beed modeled using TTFLoader of ThreeJS, where through a Mesh the relative colors have been applied. Moreover, in order to make our application responsive we add a dedicated Listener to adapt the window size based on the device resolution. Finally, to improve the user experience antialiasing has been used.

3.1 Lights and Textures

The ground texture was created by repeatedly applying a texture on a plane, using a TextureLoader. Then, the texture is added to the scene through the use of meshes that map texture coordinates into world coordinates.
A normal map has also been added to the *MeshStandardMaterial* associated with the floor, useful for creating more realistic lighting effects, as well as a displacement map, which modifies - albeit slightly - the position of the vertices of the mesh.
For the various models of the scene, the textures were imported with the model itself. For the sky, represented by a plane, a material was used which is associated with the desired blue colour.

Three directional lights have also been added to the scene. Two of them were placed on the left upper and bottom right corner respectively of the scene to reproduce a sunny day, otherwise using only one of them we obtain either dark clouds or dark objects. The third one has been introduced to illuminate texts because they are ahead of other elements and so the previous lights were not able to light up also them.

4 3D Models

In this section we explain the models we have included in our project. They are splitted into the following two categories:

- linear models: objects that are treated as an atomic entity;
- hierarchical models: objects composed by various sub-objects.

4.1 Linear Models

The linear models are models that are treated as singles entities. In our game are present the following four groups of linear models: Rifle, Trees, Clouds and Bushes. They contain 1, 4, 5 and 11 instances respectively that can be observed in Figure 1. We did this categorization to handle different kinds of objects in different ways, because objects belonging to different groups are indipendent to each other. Trees/bushes positions and orientations have been preset and remain static along the entire gameplay. Clouds positions instead, vary over time and rifle orientation can be controlled by the user. These last two aspects will be further explained in Sections 5 and 6 where we will provide technical details.

4.2 Hierarchical Models

Hierarchical models are models composed by different sub-objects that allow to represent relationships between such objects. The major benefit of hierarchical structures is the possibility to handle animations in a simple and efficient way, because, for instance, if we

want to apply a rotation to the whole object we need only to perform it to the root of the object itself, instead of applying n rotations to each individual component.

4.2.1 3D Duck Model

The first hierarchical model that we introduced in our project is an hand-made 3D model of a duck, created by us with Blender. Its structure is divided into four components: left and right wings, torso (including also the head) and legs. Such structure allowed us to reproduce the desired behavior, which consists in a simultaneous diagonal translation and a synchronous upward rotation of the wings. The above described hiearchical structure is shown in the following figure:

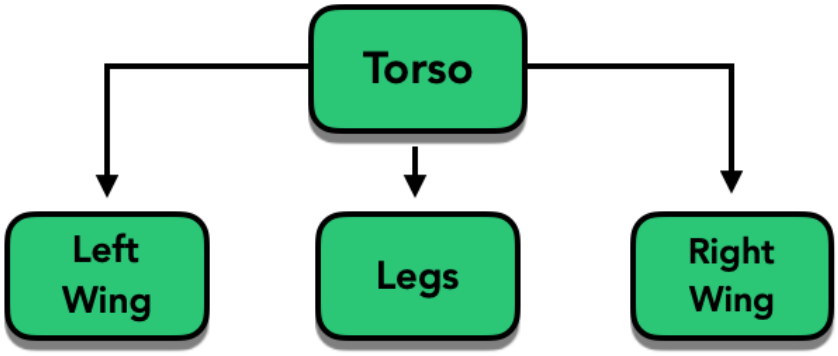

Figure 2: Hierarchical model of the duck.

4.2.2 3D Dog Model

The second hierarchical model that we used in our project is again an hand-made 3D model created by us with Blender, representing a dog. Its structure is divided into ten components: left and right upper front legs, left and right upper back legs, left and right lower front legs, left and right lower back legs, torso (including also the head) and tail.

The hierarchical structure of the dog is depicted below:

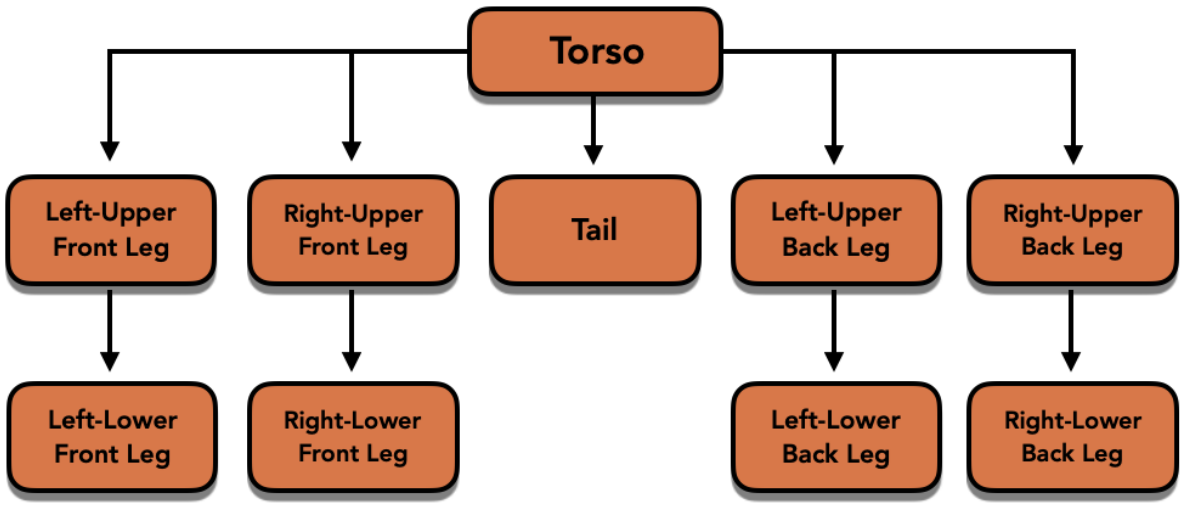

Figure 3: Hierarchical model of the dog.

We exploit such structure to let the dog move towards the bushes with few basic movements. To achieve this, we simply translate the "Torso" node, which is the root of the hierarchy tree, and automatically all other components, which are attached to it, will follow its movement. In the meanwhile, we alternate the legs movements back and forth to reproduce a walk. Additional details will be provided in the Animations section (5).

5 Animations

Following the project requirements, we have integrated four different animations into the project:

- one for the ducks (both for the movement in the sky and for the wings);
- one for the dog;
- one for the clouds in the sky.

For each animation, we have developed different solutions to ensure an effective, scalable (and not impossible to obtain) result.

5.1 Ducks' animation

The ducks' animation is the most complex one, because it can be conceptually divided into two phases: the flight of the duck with the corresponding movement of the wings and its fall once hit.
At each level, a specific number of ducks, among the 15 available, is concurrently shown in the scene and individually animated starting their flight by appearing from the grass; moreover, to ensure low predictability of the starting point and flight path and to increase the perceived difficulty, we made the whole process random.
Every time a duck is killed or it leaves the scene, a new duck is automatically generated to keep the sum of the currently shown ducks constant during the level.

The translatory movement of the ducks in the sky was obtained by interpolating a keyframe sequence. The starting position is a point having fixed y and z components (semantically it is positioned on the straight line given by the intersection of the planes $y = -0.2$ and $z = 0$) and x component randomly extracted in the [-1.1) range.
A second point is then selected, which differs by the y component and which is used to generate the trajectory. Finally, a keyframe sequence is automatically generated and saved in the i-th element of the *x_keyFramesDucks* and *y_keyFramesDucks* arrays.
These operations are carried out by calling, respectively, the *chooseStartingPoint*, the *chooseDirection* and the *generateKeyFrames* functions within the *animationBirds* function, which is responsible for updating the position of the ducks (and the rotation of the wings). The path of each duck is interrupted as soon as its position is outside the camera's field of view; to verify this, a frustum and the containsPoint method were used.

While translation is applied to the entire hierarchical model, wing rotation is applied to each wing individually. At first, we had implemented a solution based on keyframes, however, we saw that the final result was not good at all.
So we preferred to use a gradual increase (decrease) within two defined values. Each wing

is managed individually and its rotation values are reset as soon as the duck is "removed" from the game.
In this first part of the animation, we also made a distinction between left and right wing, and between a duck flying to the right and a duck going to the left.

If the rifle strikes a duck then the second part of the animation takes place: now the bird starts its fall constituted by a downward translation and a rotation by the x-axis. In this case, since it is dead, the wings do not move to make everything more realistic.
Finally, the duck is made no more visible when it reaches the ground.
This time the animation is computed not by using the keyframes but simply decreasing the x component of the rotation and the y component of the position.

5.2 Dog animation

Also for the dog, the animation consists of three types of movement:

- the translation of the entire dog group into the space;
- the rotation of the upper part and lower part of the legs;
- the tail wagging.

Moreover, the animation consists of three phases:

- at the beginning of the first level, the dog enters the scene walking. Its presence is also functional since ideally its barking causes the ducks to start flying;
- the dog maintains his position throughout the game, wagging his tail in the meantime;
- after the game over, the dog moves and leaves the scene.

All these animations were achieved by setting keyframes manually.

5.3 Clouds animation

The clouds animation is executed only during the gaming phase and it is interrupted when the game is paused or ends.
Each cloud is moved individually, however, their animation can be divided into two modalities: those that have to go to the left will see the x component of their position decrease over time, the clouds that have to go to the right will see the x component increase.

This x component is increased (decreased) until it is lower than (greater than) a certain threshold, after which the position of the cloud is restored to a predefined value, from which the process is repeated again.
The threshold is set according to the position of the cloud: those with a lower z (i.e. placed further away from the camera) need to travel a greater distance before "exiting" the screen.

6 User Interaction

6.1 Rifle

The 3D model of the rifle is positioned on the right of the camera and it is only partially visible with the aim to simulate a FPS (first-person shooter) game. When moving the mouse an event is launched and the mouseMove function is called.
This function

- computes the mouse position on the screen;
- generates a ray passing to the mouse position by using the Threejs Raycaster object;
- this ray intersects a previously defined plane (which is the same where the duck trajectories are generated on)
- passes the intersection point to the LookAt function in order to rotate the rifle to face that point in world space

Moreover, to make the game experience more realistic, a gunsight is used as a cursor. When the user clicks the mouse a "shoot" is generated. If the intersection point matches with a point of a duck mesh, that duck is killed and the "falling" animation described above is executed. In any case, a "bullet" (a white sphere) appears for some milliseconds on the screen.

6.2 Levels

As said before, the game goal is to hit as many ducks as possible. The score is increased by one each time a duck dies. When the user achieves a specific amount of points, a new level is reached and a "Level XX" text, generated through TextGeometry, is shown in the scene.
Ideally, the game can be played for an infinite number of levels, with an increasing difficulty which depends on the number of simultaneously shown ducks, their speed and the quantity of points to reach.
Each time a duck exits the screen without being shot, one of the five available errors is lost.
When the player misses five ducks, the game ends and the "Game Over" text is shown.

6.3 Start & Game Over menus

When the application starts, it immediately appears a white "Start" box.
We put our logo on the center of the box; then the user can click on "Start Game" to begin to play: basically when this is done, the box is no more visible and the game can really start.
Otherwise he can learn "How to play" or go to "Credits" in order to know something more about us.
Instead when the player finishes his chances, after the "Game Over" text, it appears a "Game Over" box through which he can read his current and his best scores and finally have the opportunity to play again.

6.4 Pause

While playing, the user can pause the game in whatever moment, except during the "level up" and "game over" phases.
It is possible by clicking the button positioned on the top left corner of the screen to which a listener event is associated.
When pausing the game, a TextGeometry representing the word "pause" is created and shown at the centre of the screen.
When the game is paused, it is not possible to kill the "frozen" ducks, which will then return to action as soon as the pause is finished.
Finally, the pause can also be activated by clicking the P key on the keyboard. The operation mode of the keyboard commands is the same as that of the button.

6.5 Sounds

We have also decided to add music and sounds to our game that the user can turn on and off at any time with the aim of making the player experience as interactive as possible.
This is basically done by creating five HTML audio objects and by switching between the play() and pause() methods.
In particular when the application is loaded, the music is turned off and this can be seen from the symbol of the music button.
If the player turns on the music (the button music image changes) he can hear a lot of effects and audios:

- when the start box is present he can hear an audio that is repeated in a loop (using the funcion loop());
- while moving from one level to another there is another audio that ends with the dog barking;
- every time that the user clicks on the screen, it generates the sound of a shoot;
- if the user clicks the pause button there is a sound to warn that the game has been stopped or resumed;
- finally, when the player loses, during the "Game Over" text, there is a sad audio that indicates that for the moment the game is ended. After this sound, the first audio starts again infinitely, until the "Play Again" button is pressed.

7 Conclusion