CS148 Homework 7 - Geometric Modeling

Grading on Monday, Nov 17 – see the pinned posts on Ed for details!

0.1 Assignment Outline

The goal of this assignment is to help you (1) get more comfortable with modeling geometry in Blender and (2) start building your scene for the final project. It is highly recommended that you use this assignment as a milestone towards your final project, since you will be able to get some preliminary feedback from the teaching team during grading. This assignment will only focus on the geometry aspect, so there will be no texturing (yet), but you should start thinking about how you want your final scene to look overall.

The actual assignment is detailed within the first few pages of this document. The rest of this PDF contains extra resources for creating your 3D geometry. Those of you interested in assembling one whole object from multiple individual pieces of geometry may want to look into parenting objects. Those of you interested in water or cloth may want to look at the simulation sections.

0.2 Collaboration Policy

All policies from here on are the same as they were for HW2. See the HW2 document for details.

0.3 AI Policy

You may use AI tools to generate HDRI images and materials to place in your scenes for this HW. You may use AI tools to generate geometry for this HW to supplement the geometry you create yourself. You may NOT use AI tools to generate anything else for this HW, especially your rendered images. All rendered images must be the final ray traced result from Blender Cycles.

Quiz Questions (1 pt)

You will be randomly asked one of these questions during the grading session:

- What is the purpose of subdivision? Why do we need to move the vertices in the process after inserting new vertices?
- What is the purpose of control points when it comes to splines? What is one practical application of splines in computer graphics?
- How are implicit surfaces used to model geometry (e.g. a sphere, water, etc)? Why are they superior to triangle meshes for modeling something like water?
- How is range scanning used to create geometry? Why might we want to use it over manually creating the geometry ourselves?
- How does physical simulation (using Newton's second law) differ from procedural geometry in shaping geometry? Give an example of when we would use physical simulation and an example of when we would use procedural geometry in computer graphics.

1 Assignment

The Final Project Handout as well as the Final Project Discussions Lecture detail all the requirements and expectations for the project. For this homework, we want you to practice setting up a scene. Treat this as an exercise in prototyping your project scene. **ALL TODOs below can be shown in one overall render (preview) if you want!**

Note that if you're working in partners, then you might want to get used to importing and exporting object `.obj` files so that you can share what you're each modeling. Alternatively, copy and pasting objects from one `.blend` file to another is an option, and this also preserves any material properties (i.e. BSDF settings) that you've put on the object. **OBJ files DO NOT store material properties, only geometric properties,** so if you need to copy material properties between files, then copy and paste is the easiest way.

1. First, sketch out your scene on paper (or using a program like Photoshop, etc). Your sketch should help you figure out what objects you need for your scene and where they should be placed. For instance, if you're doing a room scene, then you might need a table object, a bed object and a chair object. List these objects out, and then sketch out roughly where they should be in your image. The objects can be drawn as simply boxes with labels if you're not confident in your artistic skill. This is mainly to help guide yourself in laying out your scene.

2. Create from scratch one of the objects that you listed for your scene. You can use any method to create the object, including (but not limited to) modeling, sculpting, and geometry nodes (all from HW2), as well as parenting and simulation (both detailed later in this PDF). You may also use any tutorials you find online (e.g. via Youtube, etc) as long as you cite them. Then, fine tune the camera as well as the position, orientation, and scale of your object to place it according to where it is in your sketch. Remember that you can always toggle to the camera view in the 3D Viewport to see how the objects will be placed in the render.

   Show us: (1 pt) At least 1 object placed appropriately in your scene that you created. Be prepared to explain how you made your object, what resources you used, and why it complements your scene. We will NOT be giving credit if you cannot explain how your object fits into your sketch (We really want you to start working towards your project!). You can show everything via the render preview if you want (remember to be working in Blender Cycles for ray tracing!).

3. Place another object into your scene. For this object, you may use an imported model from an online resource. You can alternatively still create this object yourself if you want.

   Show us: (0.5 pt) An additional object that you found online or created placed appropriately in your scene. Be prepared to explain why it complements your scene. Once again, we will NOT give credit if you cannot relate your object to your scene! You can show this via the render preview if you want.

4. Add appropriate BSDF materials to your objects. For instance, if you're including water in your scene, then a glass BSDF for water would be appropriate. Take some time to go back to the BSDF materials from HW4 to get a feel for which might be useful for your project. Remember that the main focus of the final project is to demonstrate and leverage the power of ray tracing, so you might want to consider having reflective or transmissive materials in

your scene (think back to the elements that you coded up in HW3). Also consider how color bleeding (HW5) may come up based on the placement of your objects. You will likely want to toggle back and forth between the material preview and the render preview as you work. Stick to the material preview when editing, but swap to the render preview to view the result.

> **Show us: (1 pt) Appropriate materials for at least half the objects in your scene. Be prepared to explain why the materials you gave to your objects make sense for your scene. Once again, we will NOT give credit if you cannot relate your materials to your scene! You can show this via the render preview if you want.**

5. Add lighting to your scene, similar to how you played with point, area, etc lights in HW4. Take some time to fine-tune the position, orientation, power, etc of your light(s) to get a feel for how it will interact with your scene. Remember to aim for soft, natural looking shadows! You may also want to try environmental lighting with the HDRI or Nishita Sky models. For instance, if you're including water in your scene and give it a glass BSDF, then it will reflect the light from the HDRI or Nishita Sky pretty naturally. You will likely want to toggle between solid view and render preview as you work. Make your edits in solid view, then swap to the render preview to see the result.

> **Show us: (1 pt) Appropriate lighting for your scene. Be prepared to explain how the lighting that you have set up complements your scene. You can show this via the render preview if you want.**

6. Add an advanced feature, such as depth of field to your scene. This will likely take some time fine-tuning. If you include a volumetric effect (or area lights for your lighting), then you might want to explore denoising (**Render Properties → Viewport → Denoise** checkbox and **Render Properties → Render → Denoise** checkbox) to get rid of the graininess that may appear in the render. Turning up the samples might also be necessary.

> **Show us: (0.5 pt) At least one use of an advanced rendering technique in your scene. Be prepared to explain how the particular technique you chose helps create the scene that you envision. You can show this via the render preview if you want.**

7. Try rendering your scene using **Cycles** as an image with at least 16 samples and a short edge of at least 540 pixels. Note how long it takes. Then, experiment with upping the sample count by a power of 2 to 32 samples, then 64, etc. Similarly, experiment with upping the short edge resolution by a multiple of 2 to 1080 pixels. Use this as an opportunity to see how well and fast your computer will take to render a high quality image.

> **Show us: (0 pt) Not for grading, but if you end up encountering slow rendering times, crashes, etc, then you may want to bring it up during office hours.**

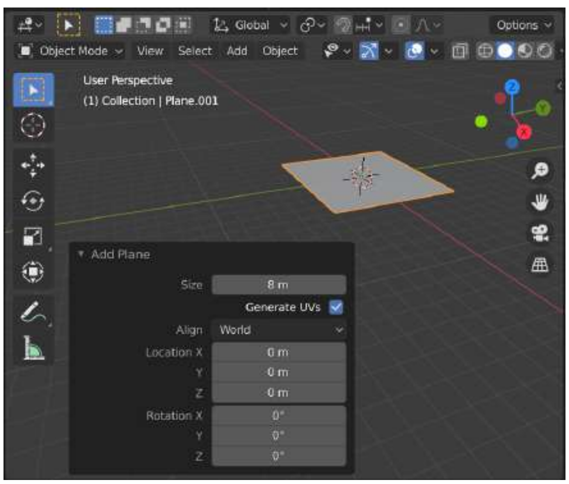
2 More 3D Modeling Techniques

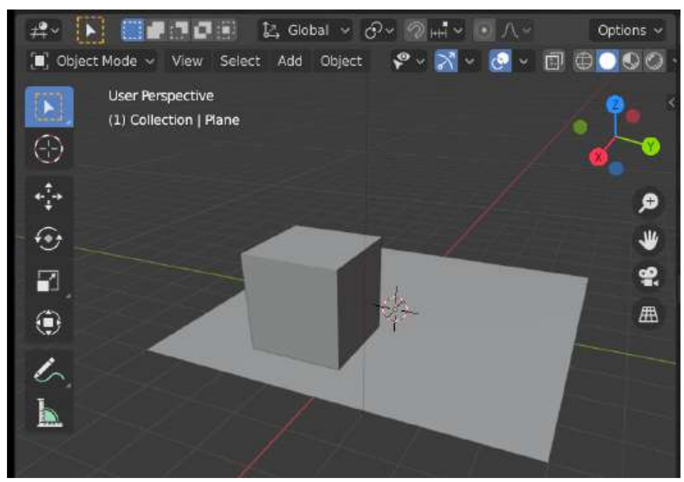
In HW2, we covered polygon modeling, sculpting, and geometry nodes as ways to create your own geometric objects from scratch. Here, we will discuss additional techniques for geometric modeling. The first is called parenting, which lets you associate one object in Blender with another. We will also introduce the idea of creating geometry via simulation and using subdivision to get finer meshes if needed.

2.1 Parenting Objects

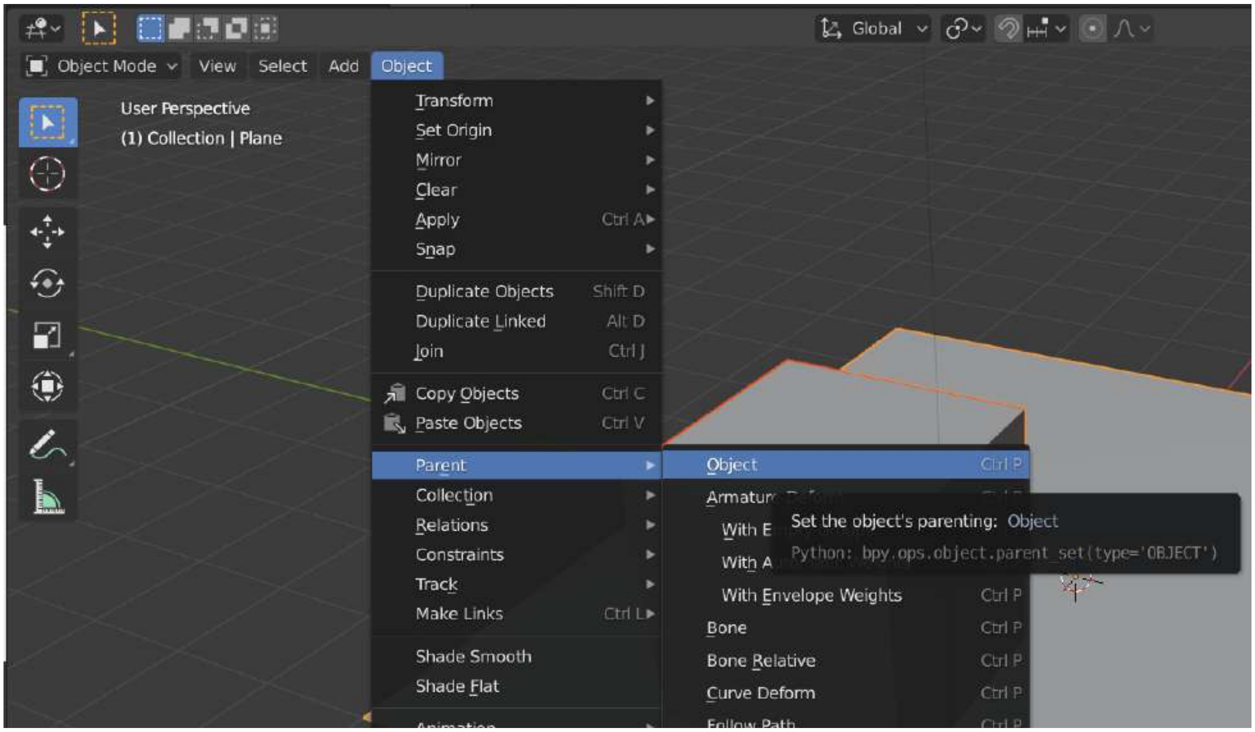
In Blender, we can make one object the "child" of another object through a process called parenting. Doing so allows us to transform both objects at the same time by simply transforming the parent object. Think of putting food on a plate, with the food being the child objects and the plate being the parent object. If you move the plate, then you would expect all the food on the plate to move with it. We'll demonstrate how to set this up with a simple example:

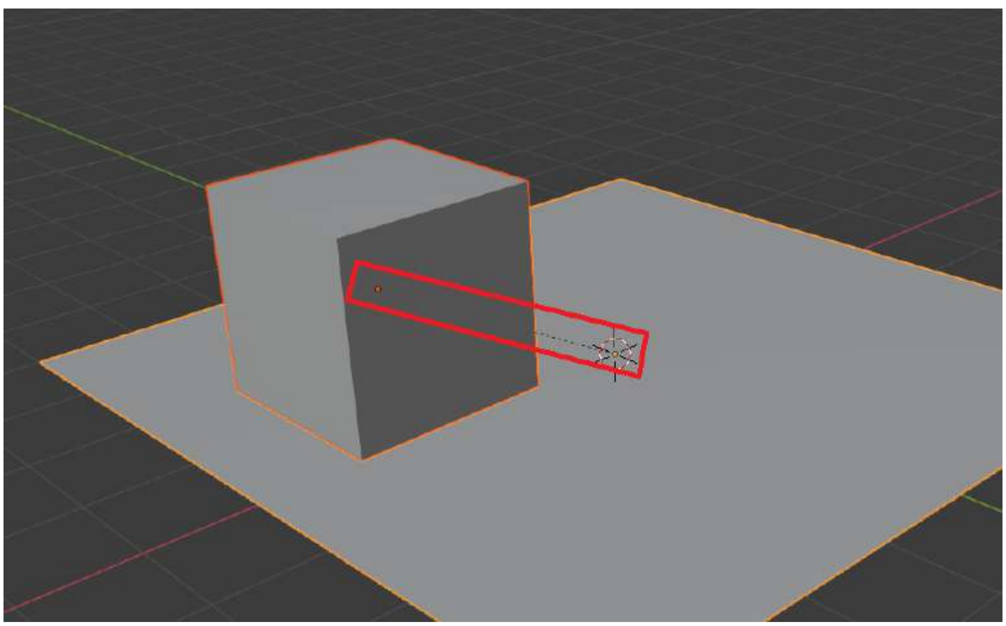
1. First, make a new Blender scene with the default cube. Set its location to (3, -1, 1). Add a plane and change its size to 10.





2. Select the cube, then hold shift and select the plane to highlight both. Go to the menu bar in the upper-left of the 3D Viewport and select **Object → Parent → Object**. A dotted line should appear between the origin of the cube and the origin of the plane, indicating that the two objects have been connected.





3. You can verify that the objects are appropriately parented by transforming the plane (e.g. translate it 5 along y). The cube should follow the exact same transformation and stay on the plane.

2.2 Creating Geometry via Fluid Simulation

Blender provides a relatively easy-to-use interface for generating workable meshes from fluid simulation(s). Let's try it out with a simple example. First, taking the default Blender scene:

- Scale the default cube to enlarge it. This large cube will become our fluid domain.
- Add a smaller cube mesh inside the default cube. This small cube will be our collision object.
- Add an UV sphere mesh above the smaller cube and inside the outer cube. This sphere will contain our liquid that gets simulated in our fluid domain.

It may help to switch to wireframe view in the Viewport toolbar when setting this up. See Figure 1 for a visual of the full setup.

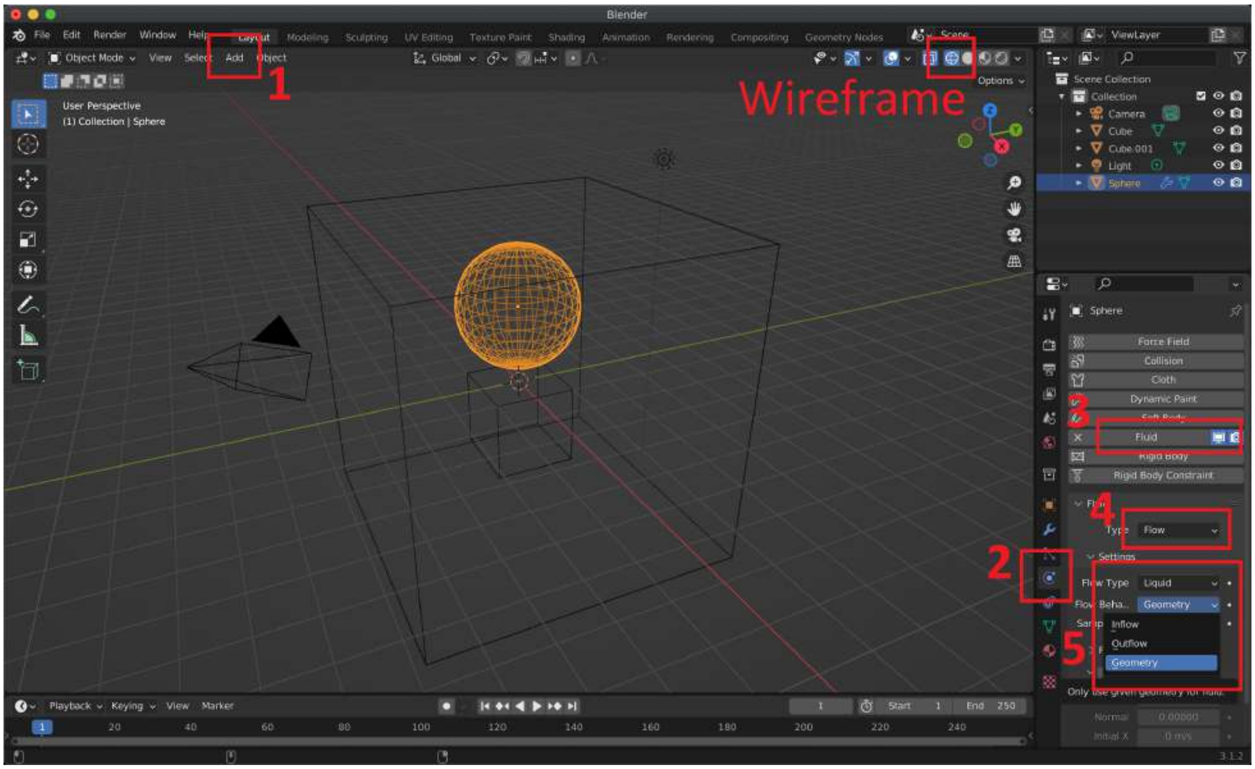


Figure 1

Start by selecting the sphere, then:

- Click on the **Physics Properties** panel of the Properties Editor (#2 in Figure 1) to access the physics options.
- Click on the **Fluid** option (#3 in Figure 1).
- Click on the **Type** dropdown menu and select **Flow** (#4 in Figure 1).
- Click on the **Flow Type** dropdown menu and select **Liquid** (#5 in Figure 1).
- Click on the **Flow Behavior** dropdown menu and select **Geometry** (#5 in Figure 1).

This sets up the sphere to be a giant collection of liquid particles. The **Geometry** option we set at the end tells Blender to have these liquid particles act as geometry when interacting with other objects in the scene (i.e. they will behave like actual mass when colliding with objects). In comparison, the **Inflow** and **Outflow** options will continuously add or delete fluid particles during the simulation, with the inflow simulating a running faucet, and the outflow simulating a drain with fluid disappearing upon interacting with the world.

Now, let's add a collision object to make the simulation more interesting. Select the smaller cube, then:

- Click on the **Physics Properties** panel of the Properties Editor.
- Click on the **Fluid** option.
- Click on the **Type** dropdown menu and select **Effector** (#1 in Figure 2).
- Click on the **Effector Type** dropdown menu and select **Collision** (#2 in Figure 2).

This sets up the cube to be an object that the sphere of fluid will collide with as it falls down in our simulation.

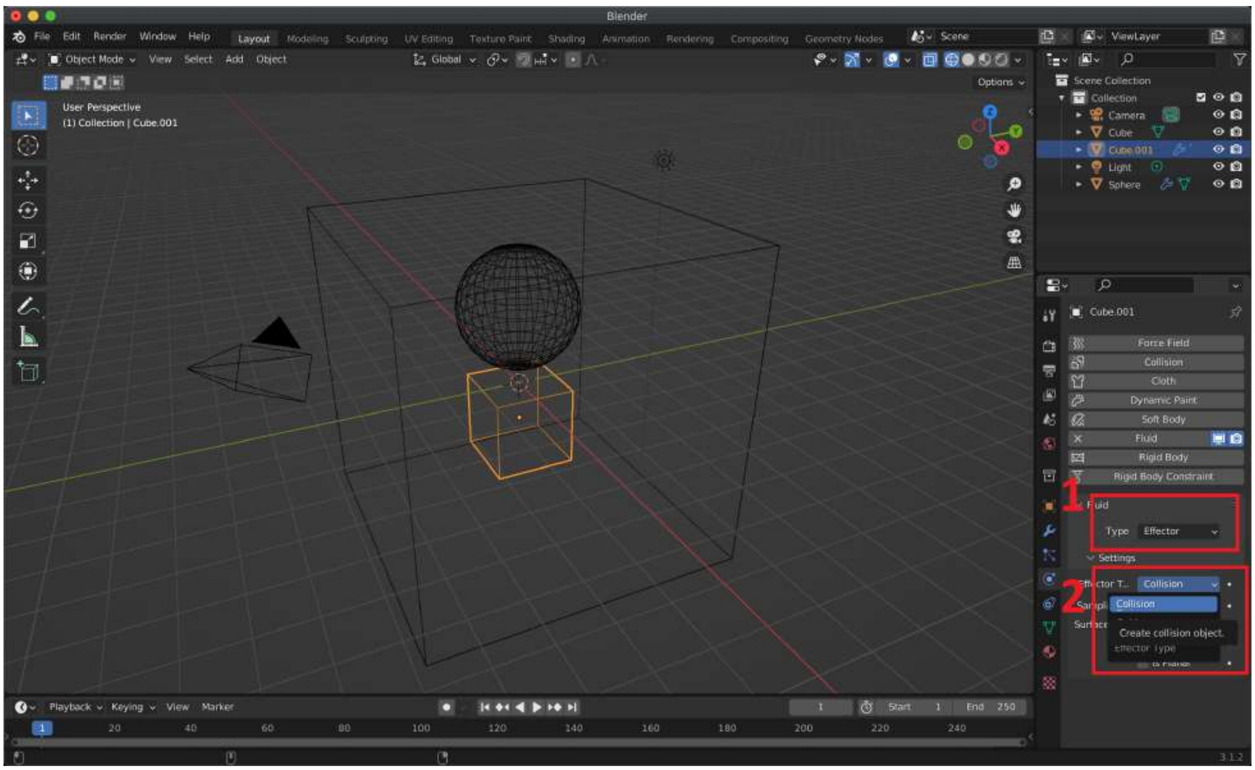


Figure 2

Finally, we need to set up the last cube in the scene. Select the large cube, then:

- Click on the **Physics Properties** panel of the Properties Editor.
- Click on the **Fluid** option.
- Click on the **Type** dropdown menu and select **Domain** to make this cube our fluid domain (#1 in Figure 3).
- Click on the **Domain Type** dropdown menu and select **Liquid** to tell Blender that this fluid domain will be used for simulating liquids (#2 in Figure 3).

This sets up the large cube to have a gravity field that will act on any liquid objects within. This includes the sphere of liquid, but not the collision cube. This means that when we run the simulation, gravity in our fluid domain will cause motion for the sphere of liquid and make it fall along the negative z-axis. But, the collision cube will stay in place. However, the sphere of liquid and the collision cube will interact, because we set the cube to be a collision object.

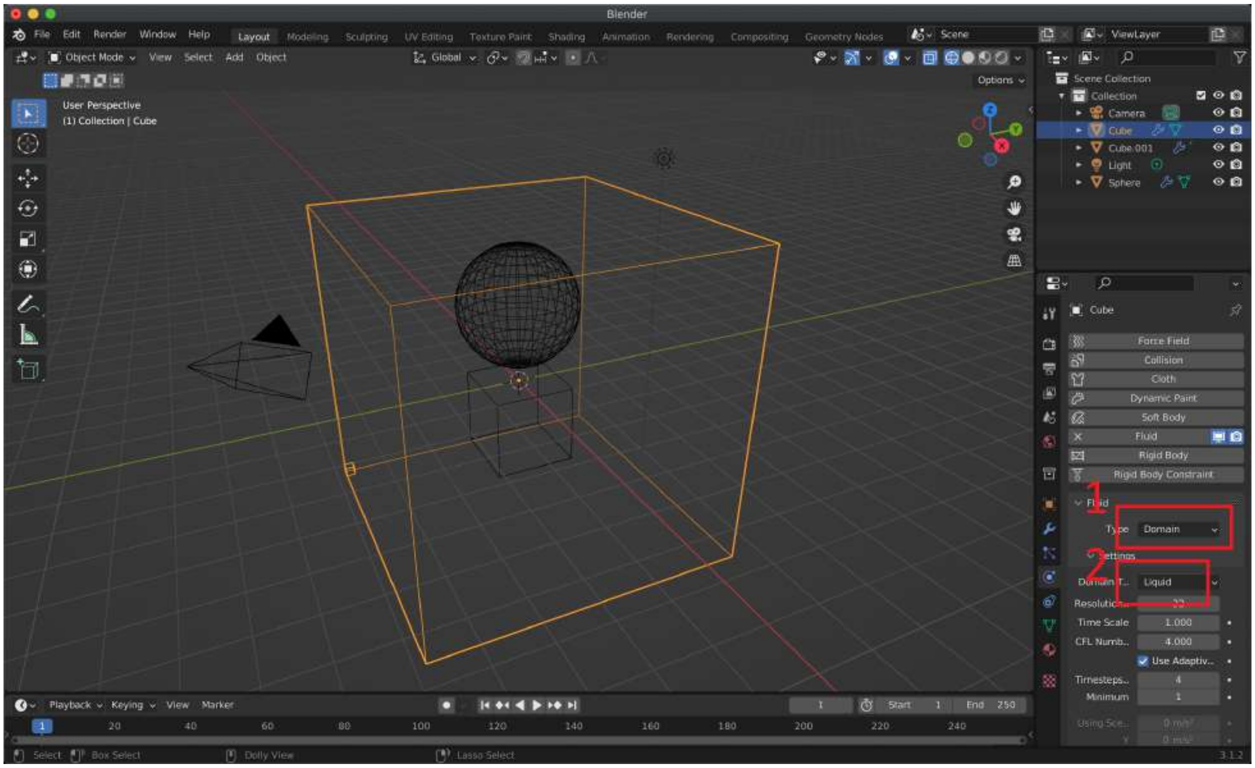


Figure 3

To actually run our fluid simulation, we need to set a few more parameters:

- Scroll down further in the **Physics Properties** panel of the large cube that we set to be our fluid domain.
- Set the **Cache** folder (#1 in Figure 4) to a folder where you want Blender to cache or temporarily save the files needed to model this fluid simulation.
- Set the **Type** for the simulation to **All** to tell Blender to generate geometry for all frames of the simulation (#2 in Figure 4).
- Check the **Mesh** checkbox to tell Blender to explicitly generate mesh geometry for the fluid simulation (#3 in Figure 4).
- Set the final **End Frame** of your fluid simulation in both the Properties editor and the **Timeline Editor** at the bottom of the Blender interface (#4 in Figure 4).
- Click **Bake All** when you're ready to generate your fluid simulation (#5 in Figure 4). It may take a few seconds for Blender to finish computing. There should be a progress bar at the bottom.

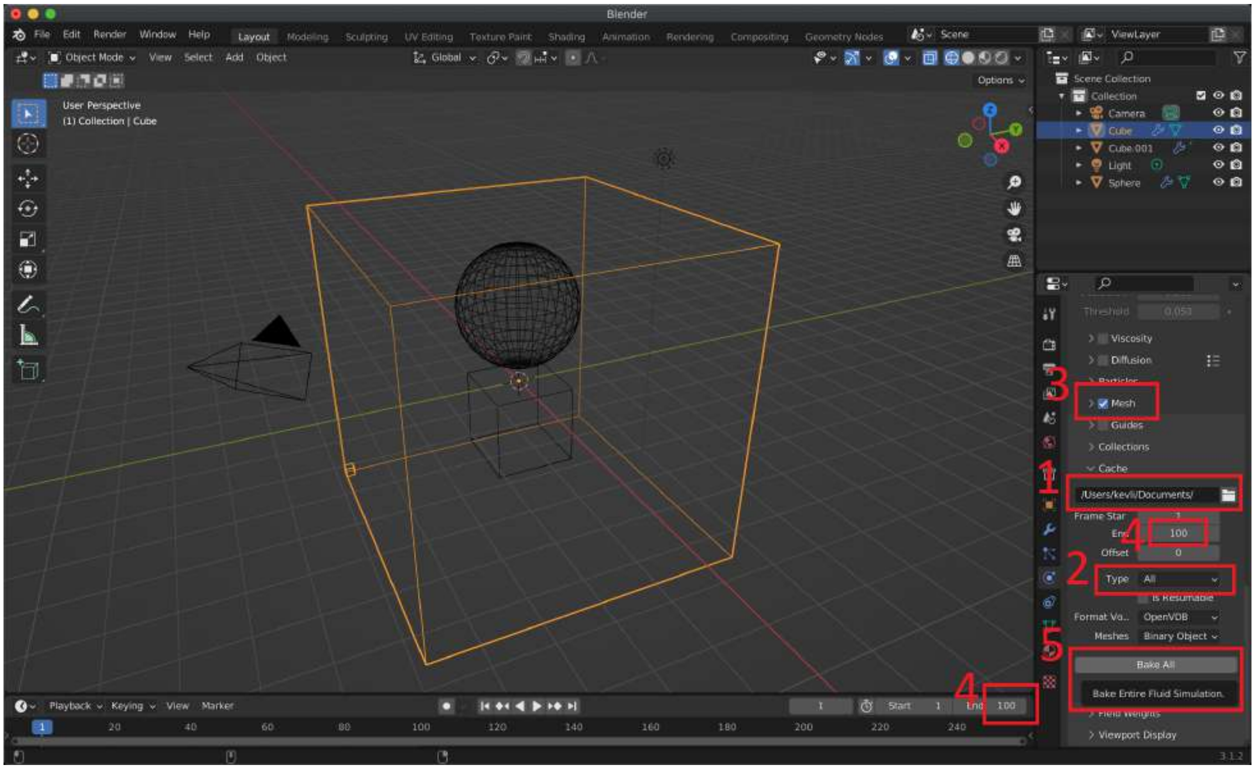


Figure 4

To see your fluid simultion in action, move the **Timeline Editor** at the bottom of the Blender interface up until you see the blue line clearly (see Figure 5). You'll see a timeline starting at 1 and ending at the **End Frame** you set earlier. You can scrub through the timeline by clicking and dragging the blue line to see the fluid simulation at different frames. For instance, Figure 5 shows us looking at the 50th frame of our simulation of 100 frames.

You may want to switch to solid view in the Viewport toolbar to get a better sense of the geometry of your fluid. If you want to redo your fluid simulation with a different set up, then you need to delete the cache files for the current simulation (see Figure 5) before modifying your scene.

When you find a frame in your simulation that you're happy with, you can export all the geometry in that frame as an .obj mesh. Simply use the **File → Export** option. Then, you can import that same .obj into your actual scene and work with it like any other geometry. For instance, in Figure 6, we show how we can transform the generated liquid mesh just like any other object. You can also add materials, textures, etc to your liquid mesh.

Warning: If you try to work off the Blender file from which you created the simulation, then you'll likely run into artifacts from the simulation set up. For instance, the fluid domain that we defined to encase our fluid simulation may end up getting rendered (which is something you don't want to happen)! So we recommend doing your simulation work in a separate file, and then exporting and importing the result as an .obj mesh to work with in a main scene file.

For more info on the parameters and the options that Blender provides for fluid simulation, see their official manual. This Youtube tutorial on the "Quick Fluid" option in Blender may be useful, especially for finding an appropriate material to give your water (in this case, the glass BSDF).

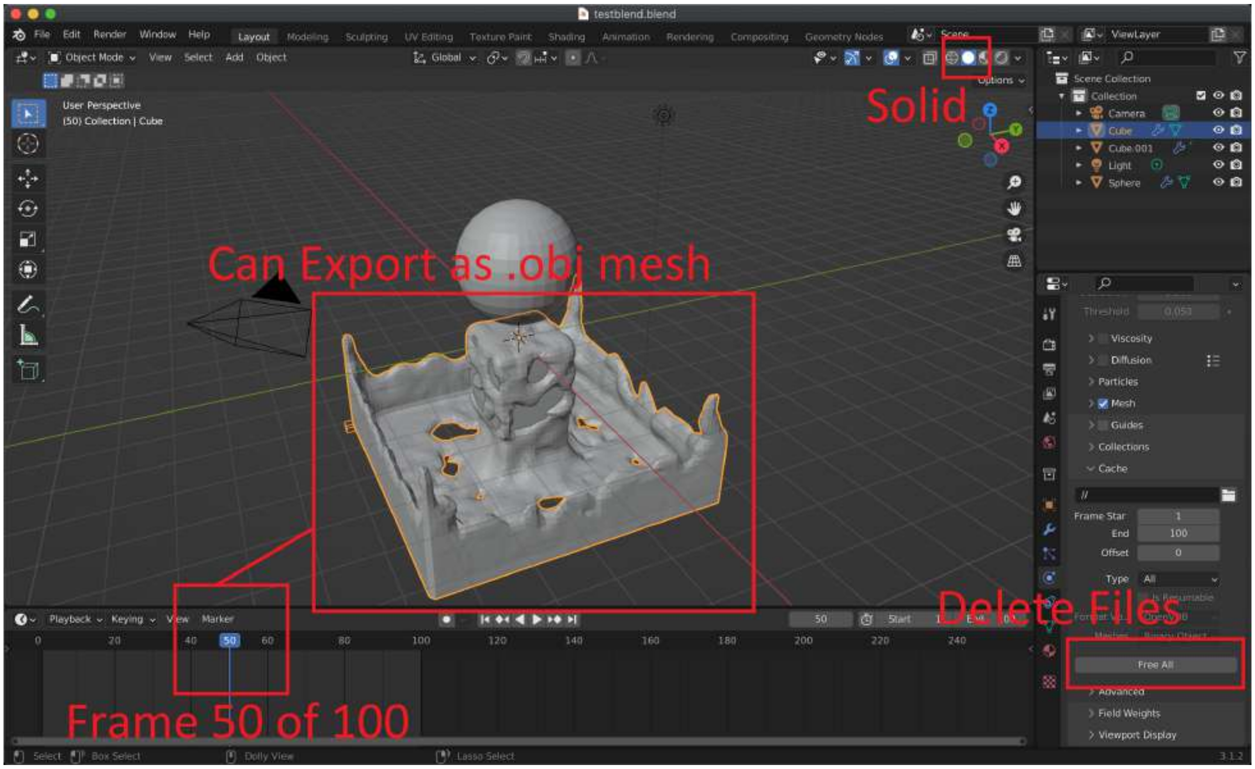


Figure 5

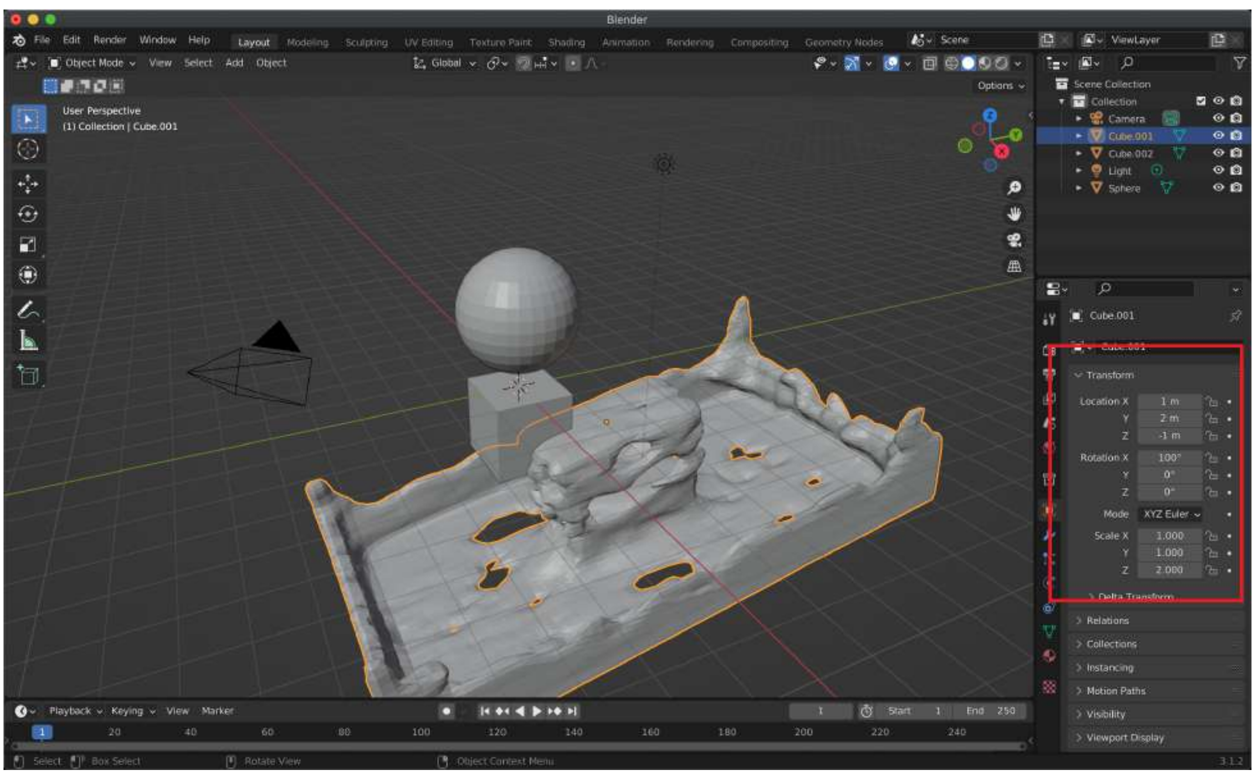


Figure 6

2.3 Creating Geometry via Cloth Simulation (and Subdivision)

Blender also provides a straightforward interface for deforming meshes with cloth simulation(s). Let's see with a simple example. Create a new scene, delete the default cube, and add a plane mesh plus the built-in **Monkey** mesh. Position the plane above the monkey head (see Figure 7) The plane mesh will become our cloth in our cloth simulation, and we'll have it collide with the monkey head.

Select the plane, then:

- Go into **Edit Mode**, then **Modifier Properties** in the Properties Editor (#1 in Figure 7).
- Click **Add Modifier** and add a **Subdivision Surface** modifier to allow us to subdivide the plane into a finer grid.
- In the modifier options, click **Simple** to use Blender's simple subdivision algorithm, which doesn't round out the edges of our plane (#2 in Figure 7).
- Right click the plane and click **Subdivide**. This will bring up a **Subdivide** control panel in the bottom left (#3 in Figure 7).
- Change the **Number of Cuts** to 50 to make the plane a 50x50 grid of squares.

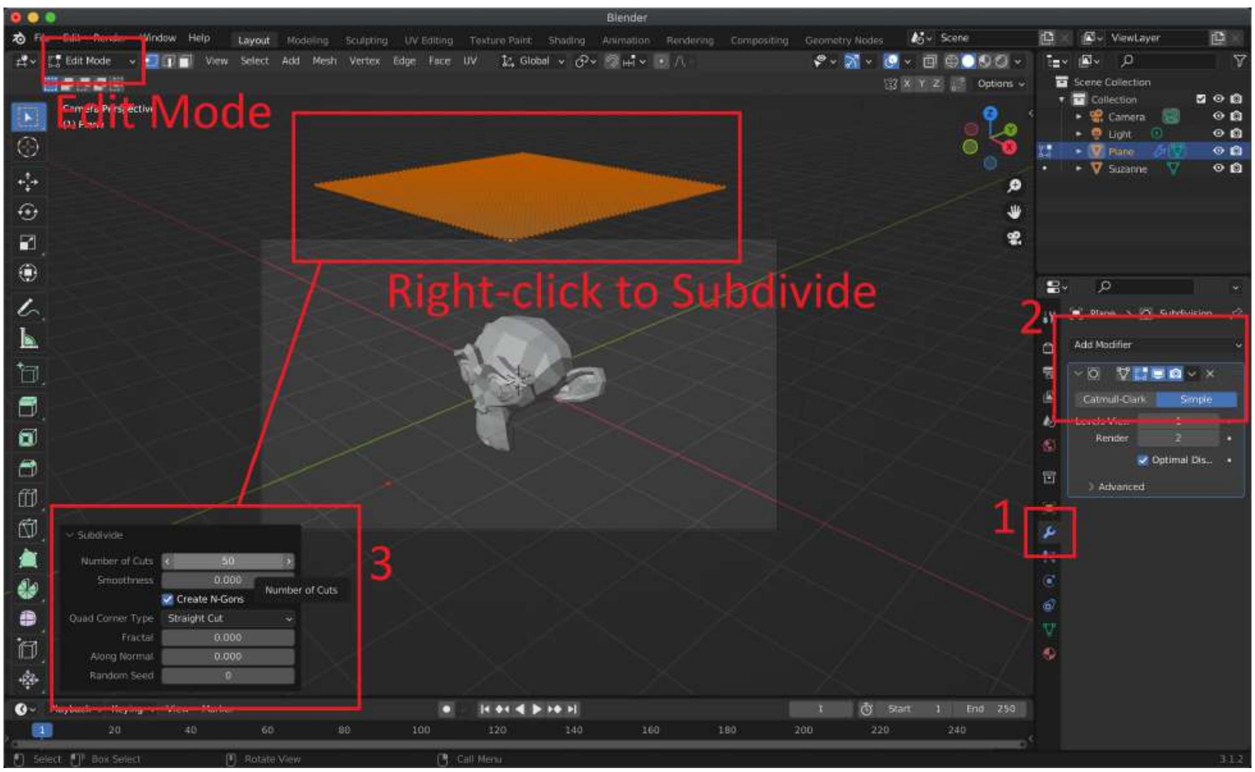


Figure 7

Now, we need to set the plane to be a cloth object and the monkey head to be a collision object.

- Select the plane (you want to go back to **Object Mode**), then click on the **Physics Properties** panel of the Properties Editor. Select the **Cloth** option. This tells Blender to treat our plane as a network of particles and springs to model the physics of a piece of cloth.

- Select the monkey head, then click on the **Physics Properties** panel of the Properties Editor. Select the **Collision** option. This tells Blender to have our monkey head interact with any objects that collide with it.

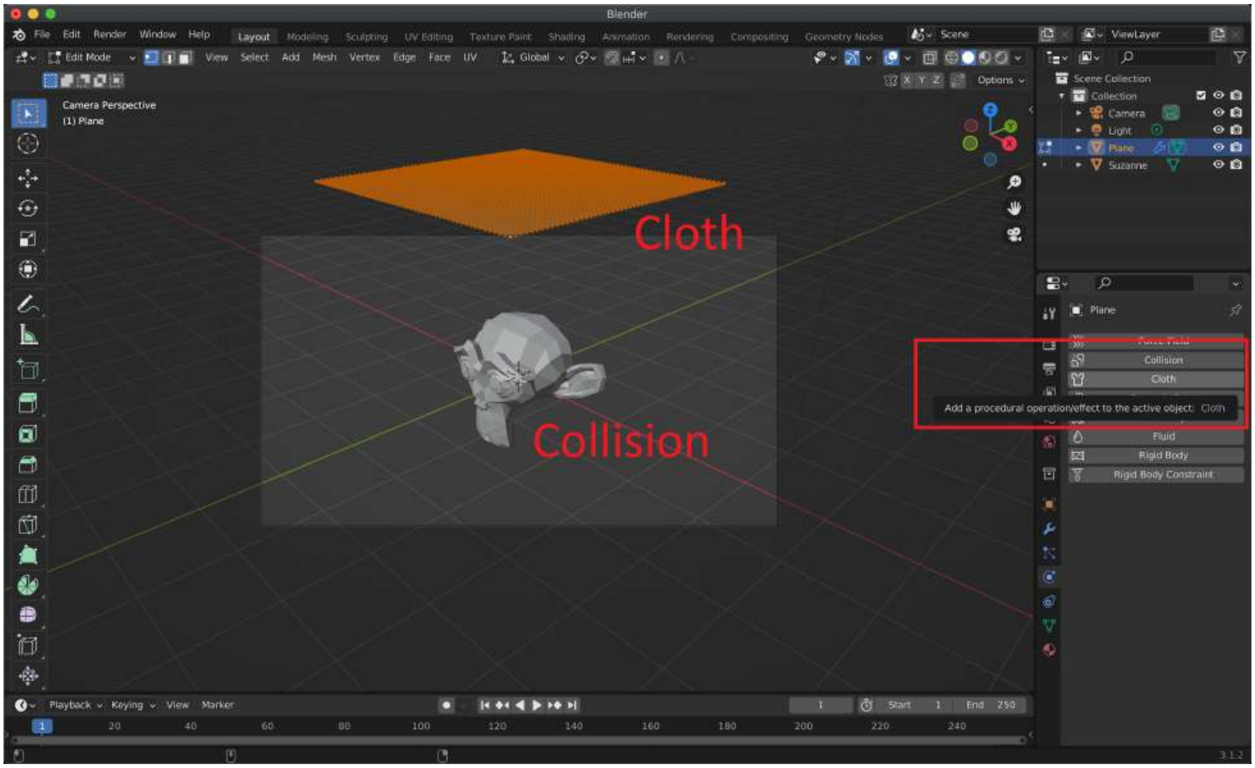


Figure 8

To see your cloth simultion in action, move the **Timeline Editor** at the bottom of the Blender interface up until you see the blue line clearly (see Figure 9). You'll see a timeline starting at 1 and ending at 250 (you can change this to another number like you did with the fluid simulation). You can scrub through the timeline by clicking and dragging the blue line to see the cloth simulation at different frames. For instance, Figure 9 shows us looking at the 31st frame of our cloth simulation.

To get a better sense of how your deformed plane looks like as a cloth, you can turn on **Shade Smooth** when right-clicking it in **Object Mode**. Make sure to change the **Render Engine** to **Cycles** for ray tracing. Then click the render preview on the viewport toolbar (see Figure 9).

When you find a frame in your simulation that you're happy with, you can export all the geometry in that frame as an .obj mesh. Simply use the **File → Export** option as usual. Then, you can import that same .obj into your scene and work with it like any other geometry.

Warning: If you try to work off the Blender file from which you created the simulation, then you'll likely run into artifacts from the simulation set up. For instance, the space in which the cloth fell during the simulation may end up getting rendered (which is something you don't want to happen)! So we recommend doing your simulation work in a separate file, and then exporting and importing the result as an .obj mesh to work with in a main scene file.

For more info on the parameters and the various options that Blender provides for cloth simulation, see their official manual. You may also find this quick curtain tutorial useful in combination with this curtain plus wind simulation tutorial.

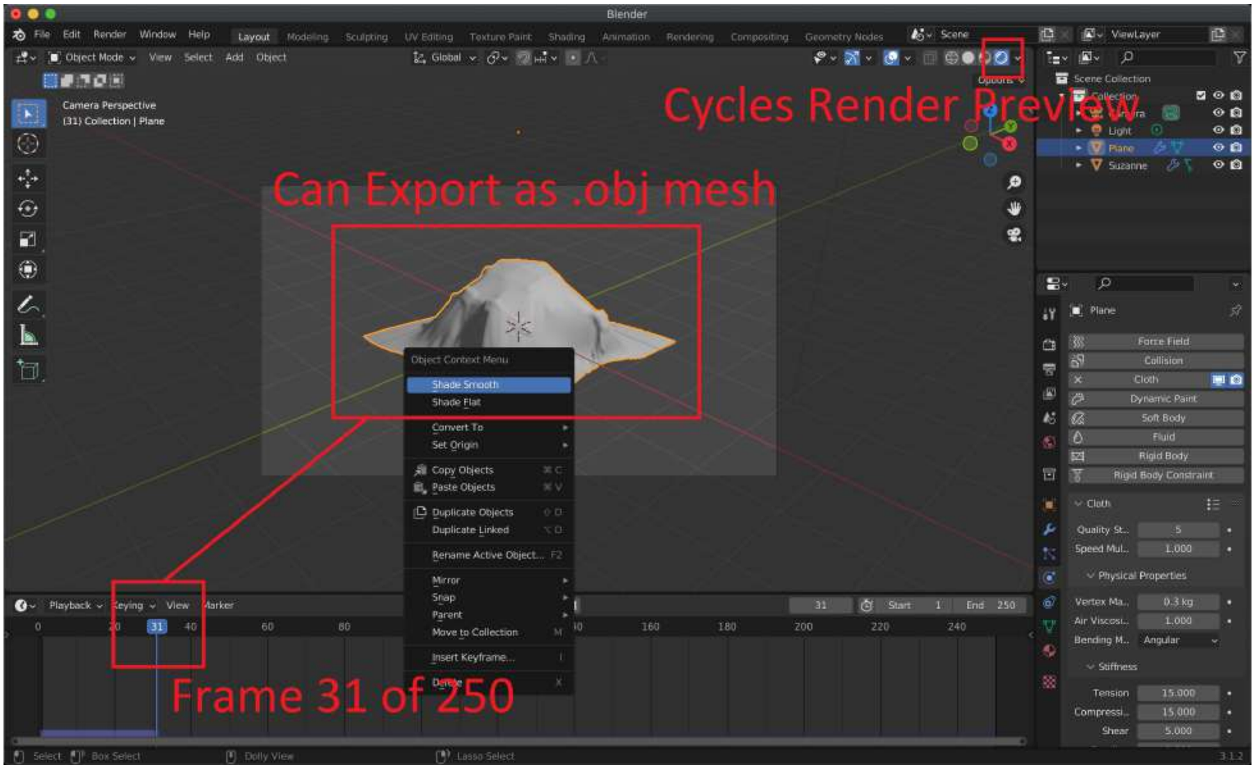


Figure 9