**CMP405 Coursework Report**

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1. **Summary**

Of the features which were outlined in the assessment brief, I chose to implement the following features:

**Usability:**

* Object selection via mouse picking.
* Multiple object selection via mouse picking.
* Use of click and drag to move, rotate and scale objects.
* User-defined camera speed parameters.
* Camera focusing on the selected object.
* Arcball camera orbiting.

**World Editing**

* Copying and pasting of the selected object.
* Object creation window.
* Object manipulation.
* Usage of multiple cameras (the object focusing uses its own separate camera to preserve the position of the free-moving camera, and both use different functions).

1. **Controls:**

**Camera Controls:**

* Use A and D to move the camera left or right.
* Use W and S to move the camera forwards or backwards.
* Use Q to move the camera up, and E to move it down.
* Hold the right mouse button and move the mouse to rotate the camera.
* Press F to focus on the object which is currently selected. Whilst in this mode, hold the right mouse button and move the mouse to use the arcball camera.
* Press R to exit the focus mode and return to the previous camera position and allow free camera movement again.

**Mouse Picking:**

* Press the left mouse button whilst hovering over any object in the scene to select it.
* Hold shift whilst selecting objects to select them all at once. This will allow you to manipulate them all simultaneously.

**Object Functions:**

* Hold control and press V to paste the object currently being selected, at a slight offset to the current object.
* When using any of the object manipulation modes, hold control and move the mouse to manipulate in the X and Y axis, or press W/S whilst holding control to manipulate it in the Z axis.
* Press delete to remove the currently selected object from the scene graph.

**UI Menus:**

* To edit camera movement speed and rotation speeds, go to File->Camera Controls, and use the sliders to adjust.
* Use the modes menu to select between normal (free moving camera), translate (move objects), scale (change object sizes) and rotation (rotate objects).
* To create a new object, go to Edit->Create Object, and fill out fields in the dialogue window which appears.
* Using the red paste button has the same effect as pressing ctrl+V and will paste the currently selected object.

1. **Features**
   1. **Mouse Picking**

Mouse picking is common in game engines and simply allows the user to select the object they want to edit from directly within the scene, making it easy to select the correct one. I decided to adapt this to also allow users to select more than one object at once, which is a feature found in both Unreal Engine and Unity, and lets the user do all the usual editing features, such as transforming, deleting or copying, but with multiple objects at once. This improves user experience because it saves a lot of time when they need multiple objects grouped together. For example, if the user were adding trees to a field, they may want to paste multiple at the same time to fill the field quicker.

* + 1. **Single Mouse Picking**

The mousePicking function in game.cpp is used to handle object selection. It first converts the mouse’s position within the window to a world position, then checks for any collisions between the mouse and objects within the scene. A check is then run over all meshes which the mouse is colliding with, then returns the object ID which is closest to the mouse’s position within the world.

Assuming that the shift key is not being held, the program then empties the vector which stores all selected IDs and adds the object ID which has just been clicked to it. This now allows other classes, such as toolMain for the transform functions, to have a reference to where the selected object is within the sceneGraph vector and edit it correctly.

* + 1. **Multi-Object Picking**

Multi-object selection works the same way as above, however if the shift key is being pressed when an object is selected, the ID vector is not emptied, and the newly selected ID is added to the end. This results in a vector which has multiple IDs in it, and whenever an object is being edited it can run through the scene graph vector at each of the position IDs within this vector.

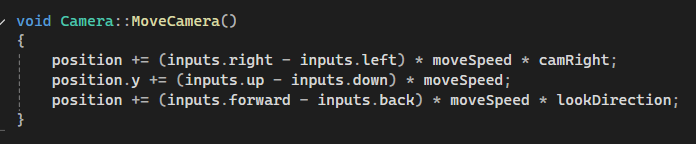
* 1. **Cameras**

The plan for the camera was to have two separate camera types. One would be a normal camera, where it can be moved around or rotated by the user, then a second camera which would allow the user to take a closer look at specific objects in the scene. The idea for this came from a combination of the scene cameras which are available in the Unity game engine. In the standard camera, Unity allows the user to move freely or select an object in the hierarchy and press F to go directly to it. It also has a prefab inspector, where the user can select a prefab from the content window and inspect its model. I decided to combine both features and put them both into the scene itself, where focusing onto an object gives you the same view you would get in the prefab inspector, but in the scene context.

Doing it this way improved the WOFCC program because it makes it easier to decide where to place objects and you can look around it to see how it looks beside the objects near it.

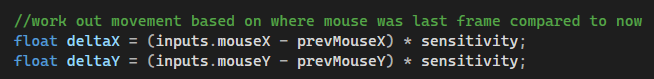
* + 1. **Camera Movement**

Moving the camera simply involves updating the camera’s position vector as shown here:

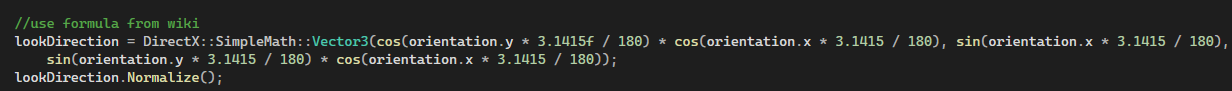


* The first line adds to the camera's position vector by taking the combined input of the right button – the left button (this would return 1 if holding D, and -1 if holding A, hence saving multiple if checks for each individual key), multiplying this by the camera’s movement speed and multiplying by the camera’s right vector to ensure the user always moves sideways based on where the camera is currently facing.
* The second line uses the same logic to affect the Y position. Note this could also have been done by adding to the entire vector with this same line of code multiplied by the camera’s current Up vector, but in this case, it directly affects the Y component individually for simplicity.
* The third line is the same again but will move towards or away from the camera’s current lookDirection, allowing the user to move forwards or backwards relative to the current view.
  + 1. **Camera Rotation**

The camera rotation is adapted from the formulas given in the lab, but uses the formula given on the wiki instead, and calculates rotation using mouse inputs instead of button presses. To do this, the rotation function is run whenever the user is holding the control key, and calculates how much the mouse has moved in the X/Y axis since the last frame, by subtracting the mouse’s position in the previous frame from its’ position in the current one, then multiplying by the sensitivity scalar value, as seen below:



These values are then added to the camera’s current orientation values, with the orientation.x being clamped between -89 and 89 because going beyond these values causes the controls to invert when looking up and down. Finally, the lookDirection vector is calculated using the formula from the wiki, before being passed back to game.cpp.



* + 1. **Camera Focusing**

When focusing on an object, the program simply activates the focus camera instead of the standard camera, which prevents the user from moving around using standard controls. Then, the FocusOnObject function in camera.cpp is run. This moves the camera position to match the object’s position, then applies a slight offset to keep the object in view. It then changes the camera’s lookAt point to be the position of the object and subtracts the camera’s position from this value to create the lookDirection vector, keeping it focused on the object.

* + 1. **Arcball Camera**

To implement the arcball camera used when focused on an object, I got the logic from a blog called A Slice of Rendering. The ArcballCamera function uses the same code as above to calculate mouse movement and then uses the built in SimpleMath function CreateFromAxisAngle to rotate around the X and Y axis accordingly. Then, using SimpleMath::Transform, the camera is rotated relative to the object’s position as opposed to its’ own, then by adding the object’s position back to the resulting matrix the camera is moved back into world space. Finally, the lookDirection is calculated by subtracting the camera’s updated position from the object position so that its’ view always keeps the object central.

* + 1. **Camera Switching**

To implement the camera switching, I first had to create a custom class to create multiple cameras. To do this, I simply moved any camera-related functions and variables from the game.cpp file to the camera.cpp file. I then made an Update function in this camera class which runs at the same time as the game.cpp Update function, and this is where I handle camera rotation, movement, etc.

Next, I created three instances of this camera class in the game.cpp file. One handles the free-moving camera, one handles the camera which focuses on an object, and one is an empty instance which has its’ variables such as position, view, lookDirection and the right vector constantly set to whichever of the other two cameras is currently active. The reason I set the system up this way is because there are multiple functions such as Draw and SetView within game.cpp which take in variables from the camera, so by having one controller instance it allowed me to set all of these functions to use this instance’s variables, meaning I did not have to use if then else checks on all of these functions individually, which could significantly decrease performance of the project.

Switching between the cameras simply works by updating the “cameraActive” bool within each camera instance appropriately, and a single if statement at the beginning of game.cpp’s Update function will set the camera controller’s variables to the camera which currently holds true in this variable.

* 1. **Object Editing**

Copying and pasting objects is a feature which is available in most game engines and is extremely useful when placing commonly used objects. By adding it to the WOFFC program, level designers would be able to simply create one instance of an object, and then quickly use it as many times as they like throughout the scene, without having to manually add more objects with the same variables, which can quickly become cumbersome and time consuming.

* + 1. **Copying**

When the user selects an object, the ID of the object is added to a vector which stores any IDs currently selected. This ID links to the objects position in the SceneGraph vector.

* + 1. **Pasting**

When the user presses control+V, or the paste button in the toolbar, the PasteObject function in toolMain.cpp is run. This function first takes the ID of the selected object and creates an exact copy of it into a new SceneObject, matching all the same variables to ensure they all have a valid value. Next, it will assign this new object its’ own ID, which is the SceneGraph.size() + 1 to ensure it is unique. The X and Z position of the new object is then slightly edited to give an offset to the position, before adding this new object to the scene graph. This process is then repeated for all objects currently selected. Finally, the display list is updated in game.cpp to add this new object onto the scene.

* + 1. **Object Deletion**

Another feature which is extremely useful for engines is having the ability to delete objects entirely. Implementing this was relatively simple since the scene graph is stored as a vector and therefore has a built-in erase function. By simply running this function on the object at the selected ID, it is removed from the scene graph, then the display list is rebuilt to reflect this on the user’s screen.

A key part of this function was sorting the vector of selected IDs in descending order. It was discovered in testing that there was often a vector out of range error when simply deleting objects in the order they were selected, since if, for example, the ID’s were selected in the order 3->2->5, in a scene with only 5 objects, then the final object’s ID is actually 3 by this point, but the function does not know this, so it still tries to delete at position 5, throwing the error. This was solved using the following line of code at the start of DeleteObject() in ToolMain:



which simply uses built in std functions to sort the IDs before deletion, therefore in the above example they would always be deleted in the order 5->3->2, meaning no IDs in the selected vector would change during the deletion, and no error was thrown.

* 1. **Object Manipulation**

Object manipulation is vital for any game engine to allow designers to move objects around the scene. It was intended to be based on the Unreal Engine object manipulation modes, where it would display the x, y and z axis around the object, however I could not work out how to display this, so I had to simplify it. This is an extremely useful addition to the WOFCC program because it allows the user to see in real-time how the object will look when manipulated, instead of constantly having to run SQL queries on the database file and then reload the program to see how it looks in the scene.

* + 1. **Using Mouse Movement**

These functions all use the same mouse logic as the camera, by subtracting its’ new position from its’ position in the last frame, so I will refer to the movement as deltaX and deltaY, the same as in the code.

* + 1. **Translating Objects**

When the mode is switched to Translate in the menu, the state in the enum of InputCommands is switched to Translate, which will then run the Translate function in toolMain.cpp during every frame where the user holds down control. This function:

* Takes in the ID in the scene graph of the object(s) being selected.
* Changes the object’s posX and posY component based on the mouse deltas, moving the object in the X or Y axis.
* Changes the object’s posZ component based on whether the user is holding W or S, moving the object forward or back in the Z axis.
* Sets the object’s components in the displayList to match its’ components in scene graph using UpdateDisplayList in game.cpp. This just updates the object on the user’s screen, since the game will display objects based on their displayList values, not what is stored in the scene graph. This function works the same as the pre-existing BuildDisplayList, however it is rewritten to target only the currently selected object, since rebuilding all objects multiple frames in a row was causing serious performance issues.
  + 1. **Rotating Objects**

When the mode is switched to Rotation in the menu, the state in the enum of InputCommands is switched to Rotate, which will then run the Rotate function in toolMain.cpp during every frame where the user holds down control. This function:

* Takes in the ID in the scene graph of the object(s) being selected.
* Changes the object’s rotX and rotY component based on the mouse deltas, rotating around X or Y axis accordingly.
* Changes the object’s rotZ component based on whether the user is holding W or S, rotating around the Z axis.
* Runs the UpdateDisplayList function in game.cpp again.
  + 1. **Scaling Objects**

When the mode is switched to Scale in the menu, the state in the enum of InputCommands is switched to scale, which will then run the Scale function in toolMain.cpp during every frame where the user holds down control. This function:

* Takes in the ID in the scene graph of the object(s) being selected.
* Changes the object’s rotX and rotY component based on the mouse deltas, scaling in the X or Y axis accordingly. This allows the user to make the object wider or taller as required.
* Changes the object’s rotZ component based on whether the user is holding W or S, rotating around the Z axis. This will increase or decrease the object’s breadth.
* Runs the UpdateDisplayList function in game.cpp again.
  1. **Object Creation**

The object creation window is designed to be a simplified way to add new objects into the scene. Without this window, adding a new object would require manually adding it into the database, by going into the .db file and running an SQL script. With the window however, the user can select the model, texture and transform of the object they wish to add into the scene. This is also a safer way to add new entries to the database, since created objects get most of their field values from an object which is already added to the database, which will help to prevent accidental invalid values being entered into the database, which could potentially cause the engine to crash.

* + 1. **Using the Window**

To access the window, the user simply goes to Edit->Create Object on the toolbar. This will open the following dialogue window:

A screenshot of a computer

AI-generated content may be incorrect.

This dialogue windows consists of two dropdown boxes, allowing the user to select from pre-defined models and texture options. These were made simply using MFC Combo-boxes. There are also input boxes allowing the user to define the starting position, scale and rotation of the object. These were added using MFC’s Edit Control boxes and setting the number parameter to True to force integer inputs only, preventing errors when the program tries to create the object.

* + 1. **Creating the Object**

To apply the user-defined variables to a new object, I first created a new class called CreateDialogue, used to handle transferring data from the window into values within the code.

The class contains two string vectors, which store the paths to valid models and textures within the project folder. These are added to the vector in the same order as they appear in the dropdown menus. By using the Combo Boxe’s GetCurSel function, this returns the position of the dropdown which the user has selected and can be used to reference that path in the vector. Next, the values entered the edit boxes are added into appropriate vectors for position, scale and rotation using GetWindowText, then \_ttoi to convert this into an integer.

From here, the CreateNewObject function in toolMain is run and takes in these vectors as parameters, as well as the path values as strings (only the selected path is passed here, the rest of the vector is not relevant). This function then creates a copy of the first object in the scene graph to make a new object with base values, which guarantees all fields in the database will be filled later and should not return any errors. This new object is then given a unique ID by adding one to the current size of the scene graph, and the position, scale and rotation of the new object are set using the vectors passed from the window. It then does the same to set the path for model and texture. Finally, this new object is added to the scene graph, and the display list is rebuilt to include this new object on the user’s view.

1. **Conclusion**

My project aimed to improve the user experience when using the WOFFCEdit framework, by adding features to simplify the process of creating and editing scenes, using functionality which is commonly found in similar applications or game engines.

The mouse-picking object selection has been vastly improved from where it started with the original framework. By allowing the user to select more than one object at once, their experience is improved by speeding up editing. In particular, the ability to highlight any objects which will currently be edited is extremely useful, as it helps to keep track of which have been selected so far, as well as making it easier to see where they are and how they look after editing. One major feature which has been omitted from this however is the ability to click and drag axis widgets. This was intended to be added however I could not work out how to do it. By adding this, it would simplify the object transform manipulation, since instead of relying on mouse movement for X and Y axis, and keyboard for the Z axis, the user could do it all by simply selecting the appropriate axis.

By implementing the ability to create an object through the window itself, this hugely improves user experience by simplifying the process of adding in objects which do not currently exist within the scene. However, this could still be improved, primarily with the addition of custom models and textures. Currently, there are only 2 objects and 5 textures available, which whilst this is better than having to rely on copying and pasting objects in the starter scene, would not really be enough to create any complex levels or scenes. Ideally, adding something similar to Unity, where custom models or textures can be dropped into the window, and the engine will add it to the options, would drastically improve this functionality. This would require extensive knowledge of the framework, and most likely a significant number of additions or editing the pre-existing classes, therefore this was not possible in the timeframe of the project.

The new camera system implemented was also a large improvement, since it makes it easier for the user to move around the scene when compared to using keys for rotating, the way it was prior to the project. The arcball camera can also prove very useful, particularly on smaller objects, or objects which are placed very closely together, and would be helpful when ensuring textures look as intended on specific models, or that multiple models are being placed relative to each other as the designer planned. Whilst this would technically be possible with the standard camera, it would be much less efficient, as it would require constantly moving the camera around the object, before rotating, and repeating this process until happy, whereas the arcball does the majority of this for you, keeping the camera a consistent distance and focused on the object. Being able to zoom in and out of objects when focusing could have been a worthwhile addition, as it would allow for even more specific focus on certain parts of the object, but I feel the camera is sufficient with its’ current implementation.

Whilst a significant amount of planning and time was spent trying to keep the code modular and simple within the code, there are some areas where this could still be significantly improved. A good example of this would be where the mouse deltas are being updated across multiple classes, being used for both the camera and object manipulation classes. Adding in a separate class which handles any mouse functions or values could help with this, as it could store the delta just once each frame, and store this as a variable which other classes could use. Despite this, overall performance of the project does not seem to cause many issues, but if this project were to be expanded this could be an important consideration.

Overall, most of the project’s functionality works as intended, and reaches the aim of improving the user’s overall experience when creating scenes. It helps the player to move around the scene easily, select and edit objects, add and remove objects from the scene, and includes some features which users will most likely be used to from other game engines, such as picking groups of objects to copy and paste them. It also retains many important features which were already included, such as the ability to save to the SQL database, allowing the user to reopen the same scene upon next use if they wish.

1. **References**

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<https://stackoverflow.com/questions/21865034/how-to-set-a-default-value-for-edit-control-box-in-a-dialog-that-is-added-to-m> - Setting the default value in edit boxes (StackOverflow), used in object creation window to enter default position, rotation and scale.

<https://learn.microsoft.com/en-us/cpp/mfc/reference/ccombobox-class?view=msvc-170> – Using the combo boxes in Forms (MS Documentation), used in object creation window to create the dropdown menus for models and textures.

<https://github.com/microsoft/DirectXTK/wiki/Rendering-a-model> - Adding new models (WFCC Wiki), used to add the fence model to the project and for changing the colour when an object is selected/deselected.

<https://github.com/microsoft/DirectXTK/wiki/Matrix> - Arcball camera functions

<https://asliceofrendering.com/camera/2019/11/30/ArcballCamera/> - Using the arcball camera (Programmer Blog), used for the object focusing camera.