CS 4624
Multimedia, Hypertext, and Information Access

Final Report
17 May 2023

Marine Blender
Virginia Tech, Blacksburg, VA 24061

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Client: Cell Matrix Corporation,
led by Lias Durbeck and Peter Athanas

Our Team: Henry Macht, Adrian Shirazi,
Mitchell Campbell, Zach Shaffer
I ABSTRACT

A model of a realistic marine environment is needed for training a rugged, onboard optical sensor designed by Cell Matrix Corporation, a VTCRC COgro member (i.e., a small company in Virginia Tech's Corporate Research Center), a project led by Dr. Peter Athanas, an ECE professor at Virginia Tech. This will be accomplished within Blender, a free and open 3D modeling and rendering tool. The chosen environment is the intercoastal waters of the Palm Beach Inlet in Florida, between the Port of Palm Beach and the Inlet, approaching the Inlet from the south side of Peanut Island. This active inlet and port area gives the scene of the Blender model.

To build an accurate representation of the specified area we will construct a terrain model for the Palm Beach Inlet water area from the Port of Palm Beach to the Inlet, including where the Intercoastal Waterway channel meets the Inlet channel, south of Peanut Island. This covers the surrounding islands and land masses, bridges, and large structures. There will also be roughly five types of boats to model (i.e., yachts, sailboats, mega-yachts, cargo ships, fishing boats, and other boats commonly found in the area), to represent different situations. Different looking classes of boats are needed to train the marine sensor to recognize them, so we choose different classes and create or find-and-customize a model for a boat from each class. The team will be provided with the trajectories of individual boats traveling this area from AIS ship tracking data published by the US Coast Guard. To simulate these realistic situations we have written a Blender script that allows boats to transit along these AIS tracks.

To account for any time of day our scene has different types of dynamic weather, waves, changing tide levels, buoys, channel markers, and boats. The whole scene has been rendered in Blender and uses the scripted dynamic scene. To help aid the camera training data we have created various camera flyovers that show the scene from a drone's-eye view, for a drone circling the area flying at heights from 5' to 40' above the water surface. These flyovers have all been rendered in Blender.

This work will advance a project funded by the National Oceanic and Atmospheric Administration (NOAA) to construct a rugged marine optical sensor for boaters that automatically detects boats ahead, and other potential obstacles. Blender scenes will be used to train the sensor prior to its deployment in environments like the one chosen for this project: busy inlets and ports.
II  ACKNOWLEDGMENTS

This project was created and proposed by Dr. Peter Athanas, who works at the Cell Matrix Corporation, which is a small company within the VTCRC COgro organization. The other main contact during the execution of this project was Dr. Lisa Durbeck, who also works with Dr. Athanas at the Cell Matrix Corporation.

The optical sensor design and implementation is currently being funded by NOAA (National Oceanic and Atmospheric Administration). Without their support the optical sensor project may not have been possible.

Dr. Fox played a crucial role in connecting Dr. Athanas, Dr. Durbeck, and the Cell Matrix Corporation with the team members involved so his help and support is greatly appreciated by all the people involved.
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1 INTRODUCTION

Small aquatic vehicle collisions are a problem in dense marine environments. This poses a risk for amateur boaters, swimmers, and marine life. Sensors exist for large-scale commercial vehicles that will detect obstructions in the water and alert the driver, however, no affordable sensors exist for amateur boaters. Cell Matrix Corporation aims to create a small and affordable sensor for amateur boaters. The sensor must be trained on data to accurately detect obstructions which will be created in a virtual environment. This was accomplished through Blender, a free and open 3D modeling and rendering tool.

1.1 Objective

Using Blender, we constructed a replica of the terrain of the intercoastal waters of the Palm Beach Inlet in Florida, between the Port of Palm Beach and the Inlet, approaching the Inlet from the south side of Peanut Island. This active inlet and port area is the scene of the Blender model environment. Not only does an accurate 3D model of the Inlet need to be constructed, but various obstacles need to be constructed as well. Along with the finished 3D marine environment, animations of boats transiting the region were constructed.

1.2 Client

Our client is Dr. Peter Athanas, an ECE professor at Virginia Tech, and Dr. Lisa Durbeck, one of the co-founders of Cell Matrix. Vice President Dr. Lisa Durbeck has expertise in full-stack engineering, algorithms, network, and hardware design. Cell Matrix Corporation is a VTCRC COgro member, a small company in Virginia Tech’s Corporate Research Center. They have received initial funding from the NASA Jet Propulsion Laboratory.

1.3 Roles

The team members worked on different aspects of the project but collaborated on the majority of the deliverables. The roles of each team member are listed in Table 1.1.

<table>
<thead>
<tr>
<th>Group Member</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Henry Macht</td>
<td>Object Management Leader</td>
</tr>
<tr>
<td>Adrian Shirazi</td>
<td>Animations Leader</td>
</tr>
<tr>
<td>Mitchell Campbell</td>
<td>Scripting Leader</td>
</tr>
<tr>
<td>Zach Shaffer</td>
<td>Testing/Integration Leader</td>
</tr>
</tbody>
</table>
1.4 Project Timeline

In the timeline shown in Figure 1.2, we give details about milestones for the overall project:

Figure 1.2: Project Timeline

<table>
<thead>
<tr>
<th>February</th>
<th>April</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/23: Familiarize with Blender</td>
<td>4/6: Create air and lighting parameterized objects</td>
</tr>
<tr>
<td>2/28: Gather assets online</td>
<td>4/20: Create the water parameterized objects</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>March</th>
<th>May</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/16: Complete static land terrain (waterway, landmasses)</td>
<td>5/2: Render animations and flyover</td>
</tr>
<tr>
<td>3/23: Render assets together in scene</td>
<td>5/4: Final touch ups</td>
</tr>
</tbody>
</table>
2 REQUIREMENTS

The requirements of this project were specifically outlined from the start of the development, but also had room for modification and adaptation throughout. As per the project description page given, the specific requirements of the project are listed below:

2.1 Terrain Model

The first requirement for this project was to create a terrain model loosely based on a specific inlet in Palm Beach, Florida. The area modeled includes an inlet, island, coastline, and beach. These various aspects are modeled in Blender to create the baseline terrain which the rest of the scene is built on. The most important part of the terrain for this project is the water, as all the objects of importance are either in, on, or around the water within the scene. Other terrain objects include nearby buildings, bridges, and large structures. Although these are very far from the cameras within the scene, they are still important to include to create a level of realism and also ensure the training data for the camera is accurate to real life.

2.2 Modeling Boats

The next requirement for a completed marine environment is the models of different types of boats that exist within this inlet and port area. The most common types of boats in this area are yachts, sailboats, mega-yachts, cargo ships, fishing boats, and others. These types of boats are also common to many other major ports in the world. Modeling the types of boats and vehicles that are common within these environments allows the training data to be as accurate as possible. The boat models for this project are mostly found and sourced from free to use websites since this was the most efficient way to create a scene that is as detailed as possible. Some modifications were made to the boats to fit the project better.

2.3 Boat Movement and Transit

Another important aspect for this project was to create movement paths for the boats to take and be rendered within the scene. These paths were provided by inspecting AIS ship tracking data provided by the US Coast Guard. They give a realistic example of where the different ships and boats go in the inlet and how far they are from each other. The speed of different types of boats also varies and is important to capture within the scene. Other boats are anchored and static within the water and fastened at docks or piers.

2.4 Scene Realism

After the main components of the project were completed, the next step was to increase the realism of the scene overall. Adding weather effects, buoys, and other obstacles within the water added to the scene and improved the quality of training data gathered from this environment.
2.5 Render Scene

After the entire scene was completed and the boats and other objects had their motion scripted and programmed, the renderings of the scene from various angles occurred. The renders in Blender can take a long time depending on the realism and number of objects within the scene, so collecting a massive amount of imagery and videos may not be feasible. The renders that are most important for the training data are static images from the perspective of a boat (where the camera would be placed), and videos from the boat perspective. Another render type that is important are flyovers of the scene from an aerial point of view that show the relative location of the different objects within the scene as they travel throughout the inlet. More renderings of the scene with different effects, camera locations, and boat movement can be completed to increase the size and amount of training data for use within the camera's algorithm. The render files are listed below with a short description of each video.

MarineBlenderOnboardShipRender.mp4 - Video render from the scene with a camera placed onboard a moving boat

MarineBlenderOnboardShipRender2.mp4 - Another video render from the scene with a camera placed onboard a moving boat

MarineBlender360Render.mp4 - Video render doing a 360 degree pan around the scene
Our client sought a realistic design. They wanted an accurate representation of the Intercoastal Waterway Inlet near Peanut Island. Our team constructed objects that are native to the area that boats need to avoid from contacting. A very common problem is that boats hit another boat in the area. So we need to model various types of boats native to the area, like the sailboat shown in Figure 3.1.

Figure 3.1: Model Sailboat

There are also static objects such as buoys, bridges and docks (see Figure 3.2) that are very common objects in the water.
In order to create so many models we used open-source Blender kits that have starter packs for objects that we need. Then we edited these objects in ways that make them fit more naturally into our surroundings. This included changing the shapes slightly, or adding a different texture to them to make them more realistic for the area. Everything is edited and rendered inside of Blender.

The optical sensor must also be able to operate in different lighting and weather conditions. In order to accomplish this we have designed dynamic objects that can be adjusted in Blender’s UI. For example we had to design the waves to have different heights and the sun to be at different angles. We also needed to design different types of fog that comes through this area and might affect camera readings.

We can create waves on very rough days with white caps on them, as shown in Figure 3.3.
We can also adjust for calmer days. As you can see in Figure 3.4 there are no white caps and the wave height is significantly lower.

After we had designed all of the objects we wanted to use in the scene, it was time to design the layout of the scene itself. We first designed where all the boats, buoys, bridges, etc. would be placed in the scene. For larger objects such as docks and bridges, we referenced satellite images to determine where to place them. For more dynamic objects such as boats we created different scenes with different amounts of boats sporadically placed to represent realistic situations. The image shown in Figure 3.5 is a rough draft of the scene with a sailboat rendered in.
4 IMPLEMENTATION

The scenes we constructed and rendered will be used as training data for an optical sensor, so it is essential that during our design of the scene we have realistic accuracy. To achieve this we first start with an accurate representation of the Intercoastal Waterway Inlet. To do this we use satellite imagery to outline the shoreline and land masses as seen in Figure 4.1:
Once we had the shoreline and land masses created, we filled in the water. After the water and terrain models were finished, we added our static models. This means populating the shoreline with docks, barges, and bridges. It also meant adding background images on the land. Figure 4.2 shows the water and island models once they were blended together properly using the terrain editing features in Blender.
After the shoreline details were added, we placed our boats in the environment. Boats were placed in realistic positions and in such a way that they have a foreseeable path to take. Along with the boats, other water features were added, such as channel markers, channel buoys, and crab trap buoys. Some examples of these models can be seen in Figure 4.3.

Figure 4.3: Environment with Water Features
After all the elements have been added to the scene we will add dynamic items such as the lighting and fog. Once all items have been added to the scene we can start to animate. Figure 4.4 shows a demonstration of the different effects lighting can have on the scene.

Figure 4.4: Environment with Different Weather Features

5 TESTING

A 3D environment modeled in Blender cannot be tested with traditional software testing methods. In order to test the environment, we simply needed to ensure that the finished product can be successfully rendered. In addition to this, we wanted to keep the file size low. To attain this, we used models that are small in size. We also only used models within the aquatic section of the environment. For the scene on land, we used a backdrop instead of creating and modeling buildings, roads, and other objects that will not necessarily be caught by the sensor. We do not have a size limit; however, we did take into consideration the bigger file sizes in our repository.
6 USER’S MANUAL

6.1 Blender Users

To use this project scene to the fullest and take advantage of the data, it is very beneficial to install the Blender software. The flyover scenes and static images can be rendered from any angle and with any modifications necessary to train the optical sensor. This will take some training as Blender is a bit overwhelming to learn for beginners, but the scene that is already created will only need some small changes to lighting, camera placement, or dynamic object movement to create a vast amount of training data for the device. Suggested modifications to the scene include object placement, camera quality, camera placement on the boats, boat travel and direction, hazard placement, and weather modifications. We recommend a systematic script-based generation of training data by producing the needed output for all combinations of the various settings of each of the scene possibilities. Training an algorithm based on machine learning requires a lot of different data and more situations that are covered within the training data will improve the output and performance of the final model and device. More detail about interacting with the project within Blender can be found within the Developer’s Manual section below.

6.2 Non-Blender Users

If the user does not wish to install or use Blender, they will only be able to use all the static images and dynamic scene renders that have already been created and rendered by the team. These will include static images and videos from the perspective of different boats within the scene as well as flyovers that show the entire inlet and the objects present within the scene. Since it is impossible to predict exactly what images or videos will be needed by a user, there are only a limited amount to choose from that have already been created and rendered. To take full advantage of this scene and get the best training data for a specific task, it is highly recommended that the user either hires a developer familiar with the Blender environment or attempts to learn some of the basics of using Blender to create the data they wish to have. The Developer’s Manual that follows this section can be referenced to help the user understand how to interact with the project and achieve their specific goals.
7 DEVELOPERS MANUAL

In order to use or modify this project, it is encouraged that the developer downloads and installs the Blender software. They do not need to know much programming to be able to modify or upkeep the project, but they do need a basic understanding of how to navigate Blender and the project structure.

7.1 Installing Blender

Blender is available for download on Windows, macOS, and Linux. A new version of Blender is released approximately every three months, so be sure to keep up to date with the latest releases. The minimum hardware requirements needed to install Blender are:

- 64-bit quad core CPU with SSE2 support
- 8 GB RAM
- Full HD display
- Mouse, trackpad or pen+tablet
- Graphics card with 2 GB RAM, OpenGL 4.3
- Less than 10 years old

To install Blender, it is recommended that you first visit the official Blender website and select the appropriate version of Blender for your operating system. You can then proceed with downloading the software by clicking on the "Download" button and selecting the version you want to install. Once the download is complete, open the installer file and follow the prompts to complete the installation process. After the installation is complete, you should be able to launch Blender from your operating system's application launcher or by double-clicking on the Blender icon on your desktop. With Blender now installed on your computer, you can open the project by dragging and dropping the file into the Blender window.

7.2 Project Structure

Assets exist within the MarineBlender directory, within two subdirectories: Dynamic and Static. Dynamic holds all the dynamic assets and Static holds all the static assets for the project. When downloading or creating new assets be sure to place them in the respective folders.

Figure 7.2 shows what the project structure looks like:
Figure 7.2: Project Structure
7.3 Modifying Files

One asset that the developer might like to change are the waves. Different wave heights and velocities can simulate different weather conditions. This will help the sensor acclimate to different weather conditions. When highlighting the waves in the Blender environment, the developer will have access to several wave options. These can be adjusted to the developers' liking. Figure 7.3 shows how settings can be adjusted.

Figure 7.3: Model Wave Options

7.4 Rendering

Rendering is the process of turning a 3D scene into a 2D image. Blender includes three render engines with different strengths:

- Eevee is a physically based real time renderer.
- Cycles is a physically based path tracer.
- Workbench is designed for layout, modeling, and previews.

For this project, we used Eevee. Eevee is focused on speed and interactivity while achieving the goal of rendering materials. To render in Blender, navigate the “Render” bar on the top of the window and select “Render Animation” as seen in Figure 7.4.
Figure 7.4: Rendering
8 LESSONS LEARNED

As a team we have learned a lot about Blender and how to create models and scenes using this software. Below is a list of some of the important notes we have taken away from our work on this project:

1. Blender is a very powerful program with tons of features. There are a massive number of capabilities, tools, and functions in Blender and learning the software is definitely not easy. There is a lot to understand and take in before you can really start using the program.

2. Using many different resources in a Blender project can be very helpful. For instance, modeling every single entity from scratch may not be the easiest or most efficient way to create a scene. We found that using some different assets we could find that were already pre-made was beneficial. We also created many custom assets as well as the terrain and water so there is definitely a balance between the amount of effort and the outcome of the product.
9 FUTURE SUGGESTIONS

Our team was very satisfied with the final product, but we all agreed that there were some aspects of the process that could be improved in the future. Here are some of our suggestions.

1. The most important fact that we can’t stress enough is to get a strong grasp of Blender’s basics before diving into the project. Blender is a powerful tool, but it’s so feature-heavy it can be overwhelming. You must learn how to use blender in the most basic ways before moving any deeper into the software.

2. Have a main scene that the whole team can work on and host that in something such as Gitlab or Github. This gives the team the ability to continually add to the scene.
10 REFERENCES


11 APPENDICES

Methodology

Marine Blender

Henry Macht, Mitchell Campbell, Zack Shaffer, Adrian Shirazi

02/14/2023

Goals of our client: Use our Blender simulation to provide data to the AI-trained sensor. The simulation should be accurate enough that the sensor can use that information to determine how these sensors behave in the real-world environment. When the simulation is finished, various flyover animations from multiple angles should be rendered with at least three boats traveling in different directions as well as boats docked at the harbor.

Goals of future users: These AI-trained sensors should hopefully be able to serve as a warning system to boaters who are traveling through the stretch of water we are simulating. Some warnings may include high sea traffic, bad weather conditions, etc. Future teams will be able to use the same Blender environment to model different boats or obstacles.

The plan for accomplishment of the goals is shown in Figures A.1 and A.2.

Table A.1 gives details on desired services.

Figure A.3 connects the services with workflows.
We need to start by creating two important models. These models are going to be a boat and a bridge. We will be repeating this flow diagram with other models, but we marked down two to begin with to get warmed up with Blender. Once we find and download the asset, the rest is simple; we make some edits to the models and then import it into our main scene and edit its location.
In this project we also have dynamic objects. One of the most important dynamic objects is the water. Water can be downloaded as a static object. Then we must write some scripts to animate the waves and adjust for different water conditions. Once the water model is fully dynamic it can be placed in our scene in the correct position. We will repeat this process later on for air and light.

Table A.1: Services Supporting the Workflows

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Input file</th>
<th>Input ID</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Boat models</td>
<td>boat.fbx</td>
<td>F1A</td>
<td>Blender</td>
</tr>
<tr>
<td>1B</td>
<td>Terrain Models</td>
<td>terrain.fbx</td>
<td>F1B</td>
<td>Blender</td>
</tr>
<tr>
<td>2A</td>
<td>Animation</td>
<td>animation.py</td>
<td>F2A</td>
<td>VSCode or similar IDE, Then implemented in Blender</td>
</tr>
<tr>
<td>3A</td>
<td>Cameras</td>
<td>N/A</td>
<td>F3A</td>
<td>Blender</td>
</tr>
</tbody>
</table>
Figure A.3: Workflows Connecting With Services