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Integrating Sites of Interest into Unstructured Mesh Generation for use in Ocean Modelling

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Abstract:

When generating an ocean model, one of the first steps is creating a 2D surface mesh of the area which is to be simulated. Software capable of automatically creating these meshes has been an area of interest for some time, as the process for creating high quality meshes by hand requires experience and is time consuming. While automated meshing solutions do exist, they tend to sacrifice mesh quality for speed and ease of use, or vice versa. Additionally, in ocean modelling, we are often focused on one or more specific areas within the space we are modelling. For example, we might be interested in natural features like an estuary, or a piece of manmade infrastructure such as a harbour. Despite these smaller subsets of an area being our primary interest, typical ocean models require simulation of a broader region to improve simulation accuracy. If these surrounding areas are complex, the mesh may take longer to generate, be more prone to errors, and the resulting simulation will require more computational power to run. We are interested in maintaining a high level of detail in the areas of the simulation that are of interest, while reducing complexity of areas further away to an appropriate level. We can introduce sites of interest into the unstructured mesh generation process to help facilitate this.

The proposed program will take the sites of interest into account during the mesh generation process, informing steps such as coastline generalization, creating the mesh size function, and post-processing. We first scan an ESRI shapefile of the area using the C++ Geospatial Data Abstraction Library (GDAL/OGR) and have the user define a site of interest within that area. Then, once we have all the points of the coastline, we will apply coastline generalization methods based on proximity to the site of interest. The area immediately surrounding the site of interest would have no generalization, with the generalization becoming more aggressive the further away from the site of interest you get. Once the generalization is complete, the points are then all loaded into GMSH, an open-source 3D finite element mesh generator. By using GMSH's API, we are able to then define a mesh size field and a mesh size function, giving us control over the size of the mesh elements, allowing us to scale them based off the distance to the coastline as well as the distance to the site of interest. We are then able to generate a 2D mesh of the area and apply post-processing to the mesh to ensure that it is ready for simulation. This includes looking for undesirable features such as over-constrained elements. We can also use sites of interest here. If the over-constrained element falls within the site of interest, we can employ more robust methods to fix it, however, if it falls outside the site of interest, less elegant solutions might be considered.

While individual parts of the proposed program have been explored through research before, we seek to combine these parts into a single, widely applicable pipeline. A. Saint-Amand, et al. (2023) investigated how spatial resolution influences hydrographic simulations on coral reef environments. To do this, they created a mesh resolution formula which considers the distance from these coral reefs as well as bathymetry and coastline proximity. However, this was developed for a specific scenario and is primarily focused on the mesh resolution. J. Yu, et al. (2013) looked at the Douglas-Peucker generalization algorithm, and explored how coastlines can be broken up into line segments and applying the generalization in parts can preserve shoreline features. However, their method utilizes a uniform level of generalization throughout, whereas for us, the generalization level will be determined by the distance from the point of interest. K. J. Roberts, et al. (2019) created OceanMesh2D, which is a MATLAB-based software for 2D unstructured mesh generation. It allows for control of mesh resolution & has automatic boundary handling functionality, which removes the need for it to perform coastline simplification algorithms. While similar to our program, the introduction of sites of interest into the process allows us to better fine tune our mesh & coastline to our needs.

Currently, the primary focus is on the coastline generalization portion of the workflow. As seen in Figure 1, the coastline generalization process splits the coastline into segments whose length is based off proximity to the site of interest (segments closer to the blue dot are smaller). Then, a tolerance (which determines the level of generalization) is

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assigned based off the distance of the segment to the point of interest. This tolerance is then used in conjunction with GDAL's topology-preserving Douglas-Peucker implementation to simplify the coastline. Figures 2 & 3 show how this generalization can differ based off distance. Eventually, this will be expanded, with different generalization algorithms (such as Visvalingam-Whyatt) being used based on proximity to the site of interest.

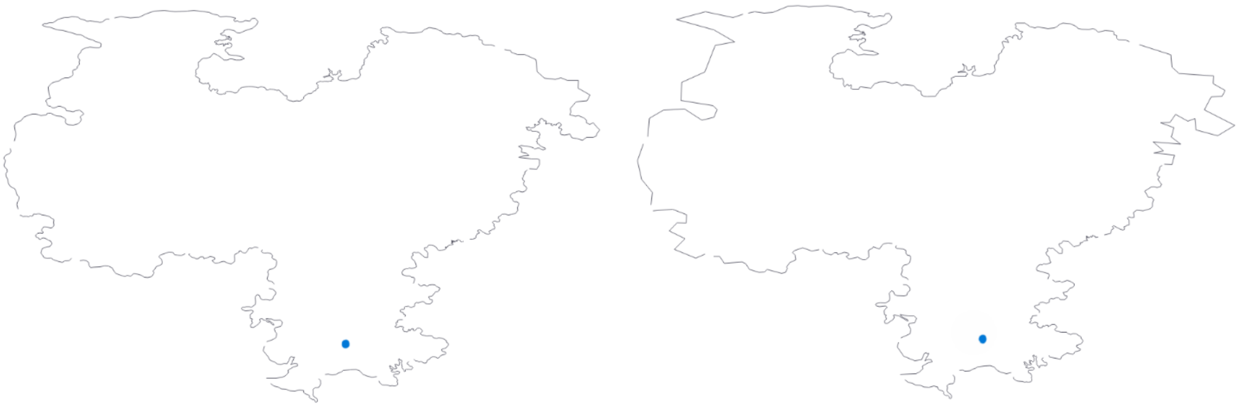

Figure 1. Before (left) and after (right) coastline generalization. The blue dot represents the site of interest.

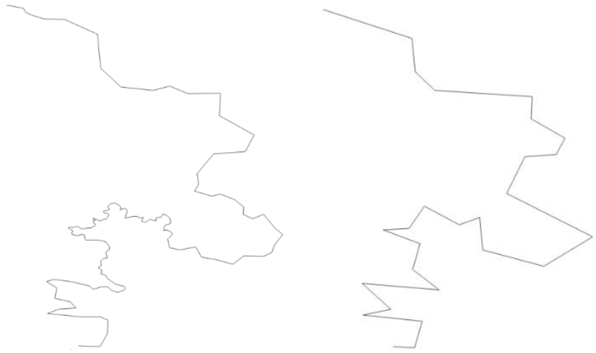

Figure 2. An example of the maximum level of generalization

Figure 3. An example of the minimum level of generalization

The goal of the program is to create meshes that maintain a high quality, and give accurate simulations, but are generated faster and are not as computationally complex to simulate as meshes generated through alternative means. The output mesh would then be used to generate a 3D mesh for ocean modelling tools such as FVCOM or Delft3D.

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