

Pre- and post-processing unstructured grids for estuary and coastal sea models with the PUG Matlab toolbox

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Introduction

Sediment transport in coastal and estuarine environments is a complex and dynamic process. Modelling approaches need to describe both hydrodynamics and sediment dynamics, as well as their interactions. This includes processes like tidal and wind wave propagation, turbulence, advection-diffusion and erosion-deposition of sediments, particle-fluid interactions, etc. As these processes may occur at very different time and space scales, there is a growing interest for using unstructured grid models to simulate them using one only multiscale model.

There are many software solutions to generate unstructured grids, but none offer satisfactory built-in functionalities to define the contour of a real domain, which can be painful to obtain. Another issue is the lack of a standard file format to save unstructured grids or model outputs. As a result, many different file formats coexist, and the choice of a specific mesh generation programme is often driven by its possible output file formats rather than its mesh generation capabilities. The PUG Matlab toolbox is developed with the aim to offer a solution to those problems encountered by many unstructured grid model users. Indeed, it gathers several functionalities to define domain contours in an integrated framework, and it can write unstructured grid files into different formats. As an example, it can be used to generate TELEMAC input files from Gmsh grids.

The objective of this paper is to present an original open source procedure to define domain contours and design unstructured grids for any unstructured grid model. This work is part of a broader research programme whose objective is to develop a multiscale mixed sediment transport model that uses TELEMAC to simulate sediment concentration, tidal and fluvial processes and wind waves in the Scheldt Estuary and Belgian coastal area.

Domain contour definition using PUG and Inkscape

PUG uses the GSHHG database to define most of the domain shorelines (Fig. 1). However, it may lack important details in some areas. PUG offers two alternatives to overcome this problem. If the area to correct is not too large, a new coastline may be defined by creating a path in Google Earth, and pointing and clicking along the land boundary to recreate its shape. If the path is exported into a KML file, PUG is able to read it and adds it to the domain contour (Fig. 2). If the area to correct is too large, and if a large data point cloud is available (e.g. bathymetry data) there, PUG computes the alpha shape of the data point cloud and adds it to the domain contour (Fig. 3).

Besides the definition of the land boundaries, it is necessary to define an open boundary offshore as well, for example at the shelf break. PUG makes use of the bathymetry data set ETOPO1 to extract coordinates along the shelf break and add a closure to the domain contour (Fig. 4).

A few manipulations are always necessary before considering mesh generation. For example: remove entire or part of lines, remove individual points, join lines, etc. This is done using the open source computer-aided design programme Inkscape, with whom PUG can interact.

Grid design using Gmsh

Gmsh is widely used in many branches of engineering, but it remains poorly known within the TELEMAC user community, probably because it does not support grid exportation to TELEMAC input files. This should not be a problem anymore, since one of the functionality of PUG is to write TELEMAC input files from Gmsh grid files.

As an example, the mesh density of the grid designed for the model of the Scheldt Estuary and the Belgian coastal area with Gmsh varies as a function of the distance to the coastlines and the distance to the area of interest (Fig. 5), and also as a function of the bathymetry and its gradient in the Scheldt Estuary (Fig. 6).

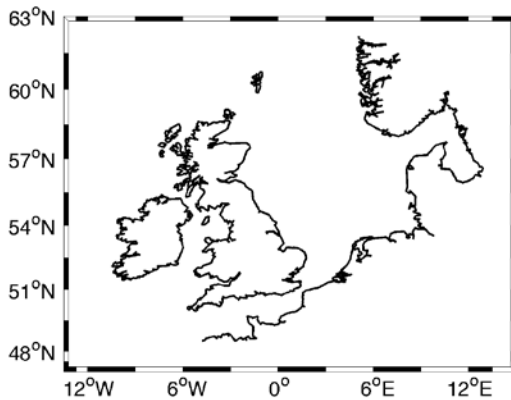


Fig. 1. Contour data from GSHHG describing the coastlines of North-Western Europe.

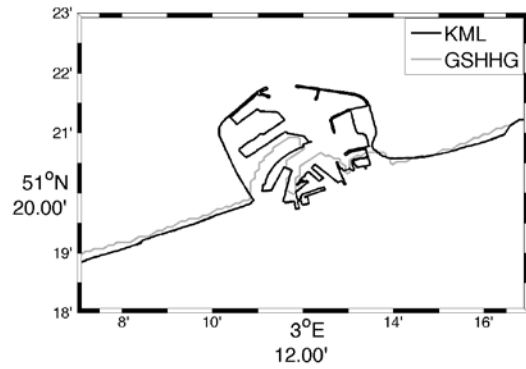


Fig. 2. Contour data from a KML file representing the port of Zeebrugge, Belgium.

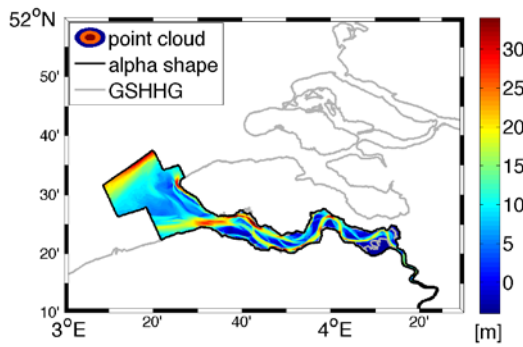


Fig. 3. Alpha shape computed from a bathymetry point cloud of the Scheldt basin.

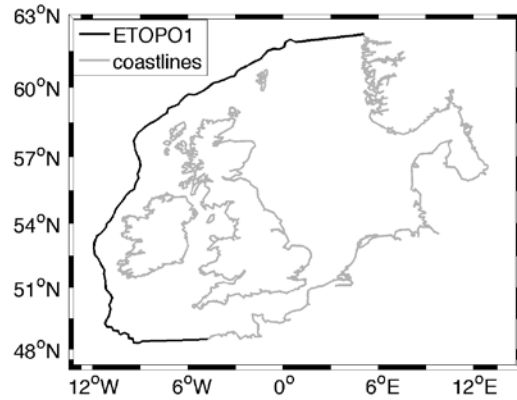


Fig. 4. Contour line 200m below the mean sea level, extracted from ETOPO1 and representing the shelf break

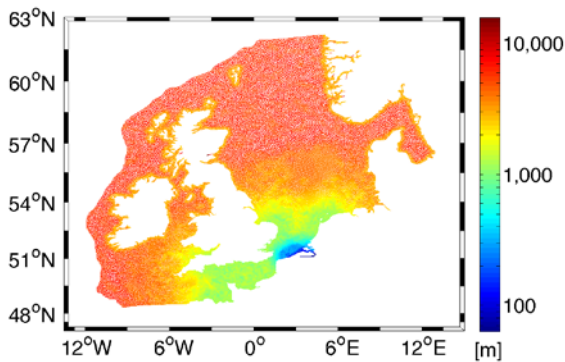


Fig. 5. Unstructured grid generated by Gmsh (261926 triangles); the colour scale gives the circumradius of the triangles.

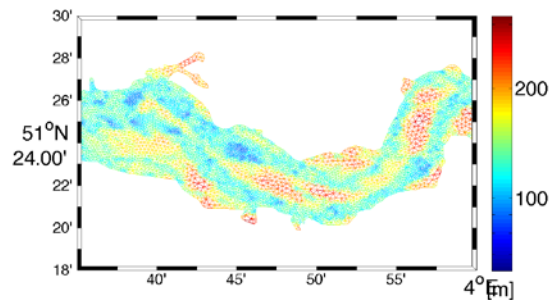


Fig. 6. Zoom on the grid of Fig. 5. to focus on the Western Scheldt, where the mesh density is a function of the bathymetry and its gradient.

Conclusion and perspectives

The development of the PUG Matlab toolbox offers an almost complete open source strategy to design unstructured grids, when used together with Inkscape and Gmsh. One can think of two reasons to believe that PUG could become very popular in the future. Firstly, the integration of different open source tools to define domain contours is unique and can be useful for any unstructured grid model user. Secondly, it provides a link between Gmsh and TELEMAC, which are very powerful and complementary pieces of software, but very little used together so far.