Integrating Mesh Refinement into ANUGA Model

Overview

The `meshrefinement` library allows you to embed remotely-sensed channel networks into your ANUGA hydrodynamic model mesh to improve computational efficiency. This guide shows how to integrate it after the "III - Mesh generation" section in your ANUGA notebook.

Prerequisites

Installation

bash

```
pip install meshrefinement
pip install rasterio scikit-image rdp triangle
```

Required Imports (add to your notebook)

python

```
import numpy as np
import matplotlib.pyplot as plt
from meshrefinement import mesh_refinement_tools as mrt
import rasterio
from rasterio.features import rasterize
from rasterio.transform import from_bounds
```

Integration Steps

Step 1: Prepare Channel Network Data

You have two options:

Option A: Use existing remote sensing data

python

```python
# Load your binary channel network image
with rasterio.open('your_channel_network.tif') as src:
    channel_image = src.read(1)
    image_transform = src.transform
    image_crs = src.crs
```

Option B: Create synthetic channel network for testing

python

```python
# Use the function provided in the full code artifact above
binary_mask, transform = create_channel_network_mask(domain)
```

Step 2: Extract Channel Network

python

```python
# Extract channel centerlines
channel_lines = mrt.extract_channel_network(
    channel_image,
    transform=image_transform,
    min_channel_length=100,  # Minimum channel length in meters
    simplify_tolerance=5.0   # Simplification tolerance
)
```

Step 3: Define Refinement Parameters

python

```python
refinement_params = {
    'max_area_channel': 500,      # Fine resolution near channels (m²)
    'max_area_background': 5000,  # Coarse resolution elsewhere (m²)
    'channel_buffer': 100,        # Buffer distance around channels (m)
    'transition_distance': 500,   # Distance for gradual transition (m)
}
```

Step 4: Apply Refinement

Method 1: Using Triangle (Recommended)

python

```python
import triangle

# Get current mesh
points = domain.get_vertex_coordinates()
triangles = domain.get_triangles()

# Create area constraints based on distance to channels
area_constraints = create_refinement_criteria(points, channel_lines, refinement_params)

# Refine mesh using Triangle
tri_input = {'vertices': points, 'segments': [], 'holes': []}
refined_mesh = triangle.triangulate(tri_input, 'q30a')  # Quality mesh

# Create new domain with refined mesh
refined_domain = SW_Domain(
    refined_mesh['vertices'],
    refined_mesh['triangles'],
    boundary=domain.boundary
)

# Replace original domain
domain = refined_domain
```

Method 2: Using ANUGA's built-in capabilities

python

```python
# Create area function for mesh generation
def area_function(x, y):
    # Calculate distance to nearest channel
    min_distance = calculate_distance_to_channels(x, y, channel_lines)

    # Return area based on distance
    return np.where(
        min_distance <= refinement_params['channel_buffer'],
        refinement_params['max_area_channel'],
        refinement_params['max_area_background']
    )

# Note: This requires regenerating the mesh from the beginning
# with the area function included in the mesh generation step
```

Step 5: Validate and Visualize

python

```python
# Check mesh quality
mesh_areas = validate_mesh_quality(domain)

# Create visualization
plt.figure(figsize=(12, 8))
plt.triplot(domain.get_vertex_coordinates()[:, 0],
            domain.get_vertex_coordinates()[:, 1],
            domain.get_triangles(), 'k-', linewidth=0.5)
plt.title('Refined Mesh with Channel Network')
plt.show()
```

Key Benefits

1. **Computational Efficiency**: Fine resolution where needed (channels), coarse elsewhere
2. **Physical Accuracy**: Better representation of flow pathways
3. **Automated Process**: Uses remote sensing data to guide refinement
4. **Flexible**: Adjustable parameters for different applications

Important Notes

- The mesh refinement should be done **after** mesh generation but **before** setting boundary conditions
- Adjust `refinement_params` based on your specific requirements
- Consider your computational resources when setting area constraints
- Test with a small domain first to validate the approach

Next Steps

After mesh refinement, proceed with:

1. Setting boundary conditions
2. Setting initial conditions
3. Running the ANUGA simulation

The refined mesh will provide better resolution in hydrodynamically important areas while maintaining computational efficiency in less critical regions.