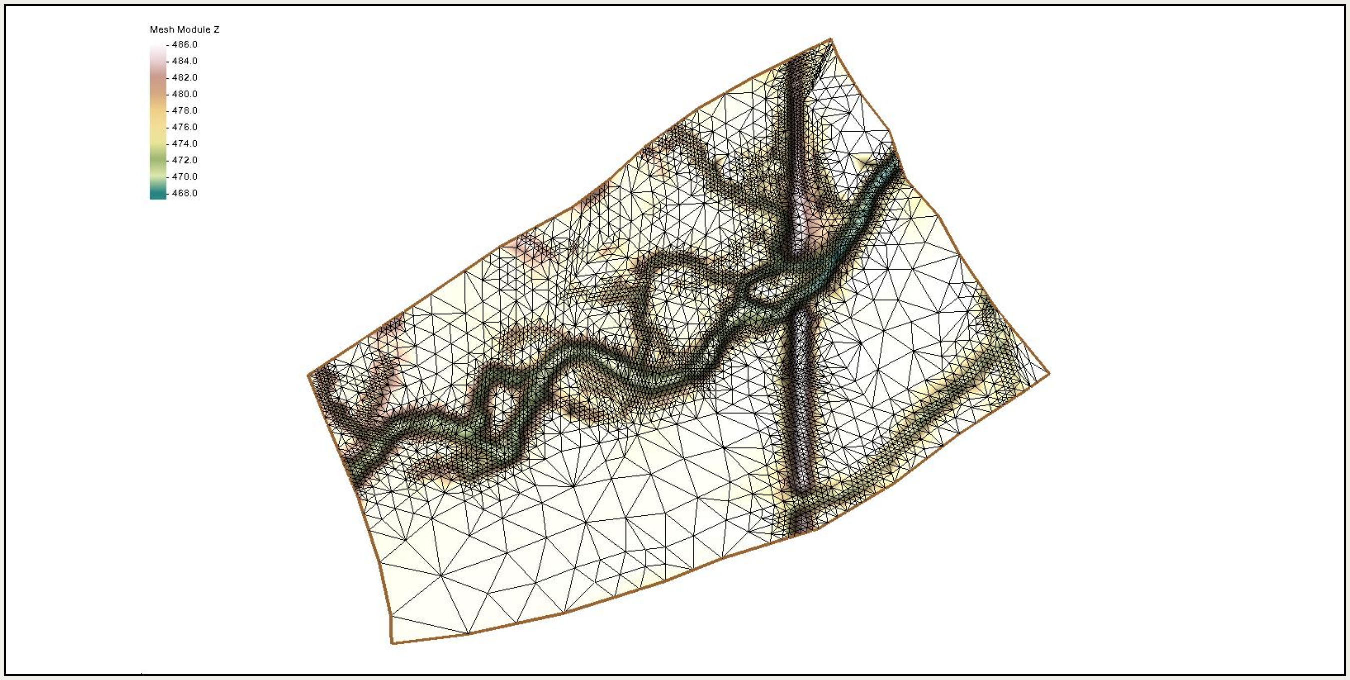
SMS 14.0 Tutorial

Automatic Mesh Refinement and Mesh Error

Refining a Mesh Based on Error



Objectives

This tutorial demonstrates how to use the *Refine 2D Mesh by Error* tool and quantify the error between a mesh and its underlying DEM.

Prerequisite Tutorials

- Overview
- Mesh Module
- Raster

Required Components

- SMS Core

Time

- 15–20 minutes

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1 Introduction

This tutorial demonstrates usage of the *Refine 2D Mesh by Error* tool to reduce the error between a mesh and its underlying digital elevation model. The tutorial also illustrates how to quantify that error.

2 Getting Started

Start by importing a project file containing an existing mesh:

1. Launch the SMS application.
2. Select *File* | **Open…** to bring up the *Open* dialog.
3. Select “Project Files (*.sms)” from the *Files of type* drop-down.
4. Browse to the *data files* folder for this tutorial and select “AutoRefine.sms”.
5. Click **Open** to import the project and exit the *Open* dialog.

The project should appear similar to Figure 1. The project contains an elevation raster, a coarse mesh covering that raster, and a couple of display themes that will be used later. Refer to the display themes tutorials for more information on creating display themes.

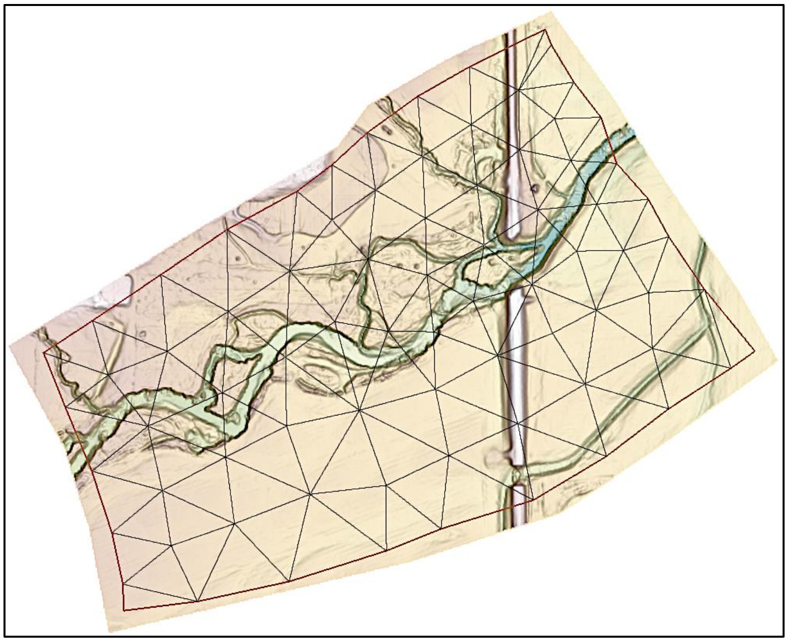

Figure 1 Initial project

3 Reviewing the Mesh Quality

The mesh provided for this region is very coarse. It does not have any points in the channel and only one point on the roadway embankment. Ideally, the mesh would have been generated from feature lines along all types of terrain-based features (refer to the *Mesh Generation from Extracted Features* tutorial). However, this coarse mesh serves the purpose for this tutorial.

3.1 Converting the Mesh to a Raster

To review how accurately this mesh represents the underlying DEM, do the following:

1. Click the **Toolbox** macro to open the *Toolbox* dialog.
2. Expand the “Rasters” folder and select the *Raster from Dataset* tool.
3. Click the **Run Tool** button to open the tool *Raster from Dataset* dialog.
4. Select the following parameters for the tool:
    a. *Dataset* select “Mesh Data/Coarse/Z”
    b. *Optional template raster:* select “GIS Data/Floodplain01.tif”
    c. *Use raster activity:* turn on.
    d. *Raster template resolution option:* select “Use template raster native resolution”
    e. *Output raster:* enter “Coarse raster”
5. Click **OK** to run the tool.
6. When the tool finishes, at the top of the *Raster from Dataset* window should say “Successfully ran tool”. Click **OK** when the tool has completed.

The new raster has been assigned default display options similar to the provided DEM, but the coarse raster is still clearly visible on top of the DEM.

3.2 Computing an Error Raster

Now, to compute the error between the DEM and the coarse mesh:

1. Return to the *Toolbox* dialog.
2. Under the “Rasters” folder select the *Raster Difference* tool.
3. Click the **Run Tool** button to open the tool *Raster Difference* dialog.
4. Select the following parameters for the tool:
    a. *Input base raster:* select “GIS Data/Floodplain01.tif”
    b. *Input secondary raster:* select “GIS Data/Coarse raster.tif”
    c. *Output raster:* enter “Coarse error”
5. Click **OK** to run the tool.
6. When the tool finishes, click **OK** to close the *Raster Difference* dialog.
7. In the Project Explorer, turn off the display of everything except “ Coarse error.tif”.
8. Right-click on “ Coarse error.tif” and select **Display Options...** to open the *Raster Display Options* dialog.
9. Click **Contour Options…** to open *Raster Contour Options* dialog.
10. Click **Color Ramp…** to open the *Choose color ramp* dialog.
11. In the *Aquaveo* folder, select the *Magnitude difference* color ramp.
12. Click **OK** to close the *Choose color ramp* dialog.
13. Turn off the *Specify a range* option.
14. Click **OK** to close the *Raster Contour Options* dialog.
15. Click **OK** to close the *Raster Display Options* dialog**.**

The raster should appear similar to Figure 2

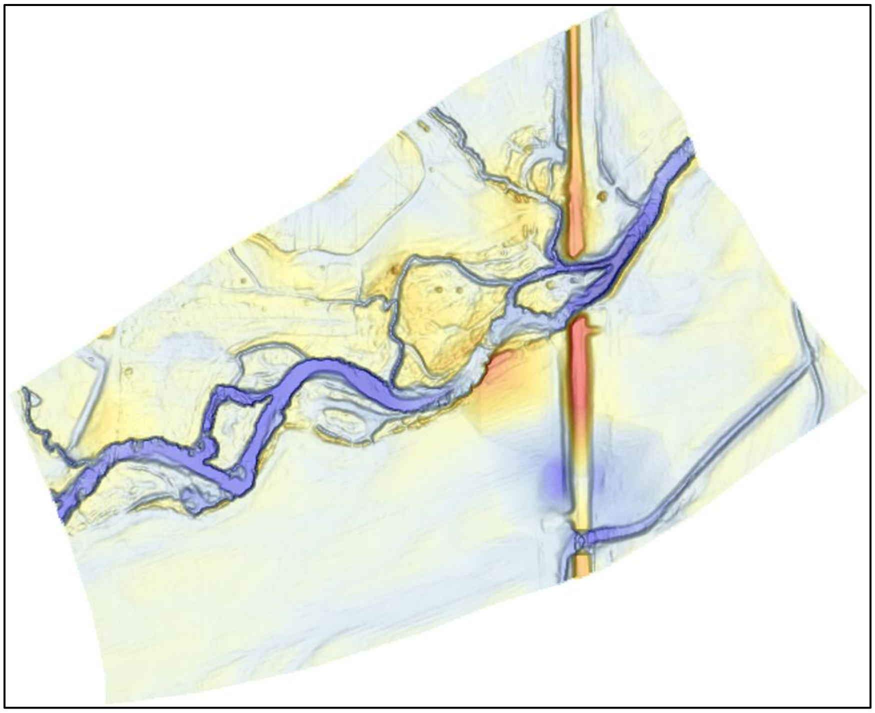

Figure 2 Error between the Coarse mesh and the DEM

This raster appears very similar to the DEM. In this case, that is undesirable because it illustrates that all the features in the raster (the channels and embankments) have significant errors. This means the features are not included in the mesh. In this case, the features raster should be adjusted to appear as all low values (a constant color).

16. Select " Coarse error.tif" to make it active.
17. Drag the mouse over the raster and review the error values displayed at the bottom of the screen.
18. Right-click on " Coarse error.tif" and select **Properties…** to open the *Properties* dialog.
19. Note the min and max *elevation*, which in this case represent error.
20. Click **OK** to close the *Properties* dialog.

4 Auto-refine the Mesh

SMS has a tool to automatically refine the mesh in regions where the error is above a specified threshold. To run this tool:

1. Return to the *Toolbox* dialog.
2. Under the "2D Mesh" folder select the *Refine 2D Mesh by Error* tool.
3. Click the **Run Tool** button to open the tool *Refine 2D Mesh by Error* dialog.
4. Select the following parameters for the tool:
    a. *Mesh:* select "Mesh Data/Coarse"
    b. *Output mesh name:* enter "Iter 1"

   c. *Error threshold:* enter "1.0"
   d. *Maximum iterations:* enter "1"
   e. *Raster 1 (highest priority):* select "GIS Data/Floodplain01.tif"
5. Click **OK** to run the tool.
6. When the tool finishes, click **OK** to close the *Refine 2D Mesh by Error* dialog.
7. In the Project Explorer, turn off the display of all the raster data.
8. Turn on the display of both " Coarse" and " Iter 1" meshes.
9. Switch back and forth between the two meshes.

Note that almost all edges in the coarse mesh were split into two edges. This indicates that the error along those edges was greater than the specified threshold of 1.0.

10. Return to the *Toolbox* dialog.
11. Select the *History* tab and expand the most recent folder.
12. Select the most recent *Refine 2D Mesh by Error* and click the **Run Tool from History…** to open the *Refine 2D Mesh by Error* dialog with the values from the last run.
13. Change the *Maximum iterations* to "2" and the *Output mesh name* to "Iter 2".
14. Click **OK** to run the tool.
15. When the tool finishes, click **OK** to close the *Refine 2D Mesh by Error* dialog.
16. Repeat steps 10–15 changing the *Maximum iterations* to "3" and the *Output mesh name* to "Iter 3".
17. Again, repeat steps 10–15 changing the *Maximum iterations* to "4" and the *Output mesh name* to "Iter 4".

Note: running the tool multiple times is for illustrative purposes to compare the changes. However, this technique may be of value in real applications as well.

18. Turn on the display of all the meshes and switch between them. Note the areas where refinement takes place.

The refine process on the mesh splits any edge that has an error along the edge greater than the specified error threshold.

5 Reviewing the Results

The next phase of this workflow would be to repeat the process outlined in section 3 above to create a raster for each of the four new meshes (" Iter 1" through " Iter 4") and an error raster for each of them as well.

For this tutorial, skip these repetitive steps and load in a project with those steps completed.

5.1 Loading a Solution Project

To load the project with the four error rasters computed:

1. Select *File* | **Open…** to bring up the *Open* dialog.
2. Select "Project Files (*.sms)" from the *Files of type* drop-down.

3. Browse to the *Solution* folder for this tutorial and select “AutoRefine.sms”.
4. Click **Open** to import the project and exit the *Open* dialog.
5. If asked “Do you want to delete existing data?”, click **Yes.**

5.2 Reviewing the Error Rasters

To compare the error in the four refined rasters, repeat the final steps outlined in section 3 above. They are repeated here for convenience:

1. Turn off the display of everything except one error raster (i.e. “ Iter 1 error.tif”).
2. Select the error raster that is turned on to make it active.
3. Drag the mouse over the raster and review the error values displayed at the bottom of the screen.
4. Right-click on the visible error raster and select **Properties…** to open the *Properties* dialog.
5. Note the min and max *elevation*, which in this case represent error.

Remember that for error rasters, the elevation is the error.

6. Click **OK** to close the *Properties* dialog.

5.3 Reviewing the Average and Standard Deviation of the Error

Currently SMS requires that data in raster format be converted to a scatter set to review statistical properties. To do this, loop through each of the five error rasters and do the following:

1. Right-click on the raster and select *Convert To* | **2D Scatter** to open the *Raster Scatter* dialog.
2. Click **OK** to close the *Raster Scatter* dialog and convert the data.
3. Right-click on the “ elevation” dataset on the new scatter set and select Rename.
4. Enter “err” as the new name.
5. Return to the *Toolbox* dialog.
6. Under the “Datasets” folder select the *Dataset Calculator* tool.
7. Click the **Run Tool** button to open the tool *Dataset Calculator* dialog.
8. Enter the following parameters:
    a. *Grid source selection:* select “Scatter Data/Iter # raster.tif”.
    b. *Data location selection:* select “Points”.
    c. Below the *Dataset table*, click the **Add Row** button.
    d. In the *Dataset* column select “err”.
    e. *Mathematical expression:* enter “where (d1 < 0, -d1, d1)”.
    f. *Output dataset name:* “abs err”
9. Click **OK** to run the tool.
10. When the tool finishes, click **OK** to close *Dataset Calculator* dialog.

11. Right-click on the new " abs err" dataset and select **Properties…** to open the *Properties* dialog.
12. Scroll to the bottom of the properties and take note of the *Mean* and *Standard deviation*.
13. Click **OK** to close the *Properties* dialog.

Note how the mean absolute error and standard deviation both decrease as the number of refinement iterations increase. The mean error drops from 1.39 for the coarse mesh to 0.25 for the " Iter 4" mesh. Similarly, the standard deviation reduces from 1.91 to 0.37.

5.4 Reviewing the Refined Meshes

To review the results of the auto-refine operation:

1. In the Project Explorer turn off the display of everything except the five 2D meshes.
2. Select "Mesh Data" to make it active.
3. In Project explorer, click on Display Themes to expand the dialog, then click on View to expand.
4. Click on the " Oblique elevation" theme to set the view to an oblique view of the mesh.
5. Select each of the meshes in turn to review the impact of the refinement.

6 Comments on Mesh Quality

It should be noted that this is not a means of creating an efficient mesh. Refinement is potentially applied to all portions of the domain, hile refinement is applied where the error is large, it does not explicitly focus on features. The adaptive refinement does not give a truly smooth gradation in element size.

This approach can also result in poorly shaped elements, which may be a concern depending on the numerical engine you are intending to use.

You may want to post process the mesh that comes out of the auto-refine tool in one or more the of following ways:

- Use the *Nodes* | **Reduce Nodal Connectivity** tool to reduce the valence.
- Use the *Elements* | **Fix Bad Size Transition** tool to improve the mesh.
- Create a size function to serve as the basis of a smooth gradation mesh. This involves the following workflow:
  - Use the *Datasets* | **Point Spacing** tool to compute the spacing of the resultant mesh. This is an initial nodal spacing function.
  - Use the *Datasets* | **Smooth Datasets** tool to smooth out the nodal spacing function created in the previous step.
  - Generate a new mesh using the smoothed nodal spacing function.

7 Conclusion

This concludes the “Auto-refine Mesh” tutorial. The tools demonstrated in this tutorial can be used to improve the level of accuracy with which a mesh represents a DEM.

This tool can also be used to convert any raster data to representative point sets. One example of this would be to convert a raster nodal spacing function to a scatter set representing the same nodal spacing.