Assignment 2
Height Field and Isolines

Scientific Visualization 2022/23 (WMCS018-05.2022-2023.1A)
v1.0

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1 General Information

The assignment is designed to be addressed alongside the lectures, with the individual tasks covering what has been discussed in the respective week. Such topics as height plots visualization and isolines are covered in this assignment.

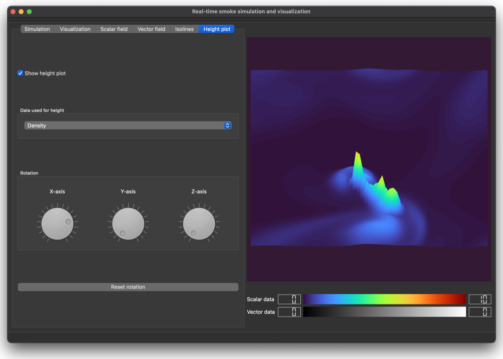
2 Tasks

Task 1 – Height plots (12 points)

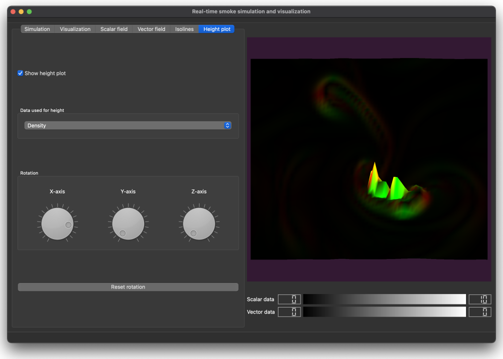
In this task, you need to implement height plots for visualizing scalar data. For this, you need to consider C++ source code in `visualization.cpp`, as well as vertex shader (`heightplot_clamp.vert`) and fragment shader (`heightplot.frag`)[1]. See Chapter 2 in the course book for background information. Complete these steps below (also see comments in the provided source files, Figure 1 shows intermediate results).

- Map the height value to color using the color map from the previous step by adapting fragment and vertex shader. The color map covers a range of height values in the range [`clampMin`, `clampMax`], height values that are smaller or larger need to be clamped to this range to determine the color (see Figure 1a).

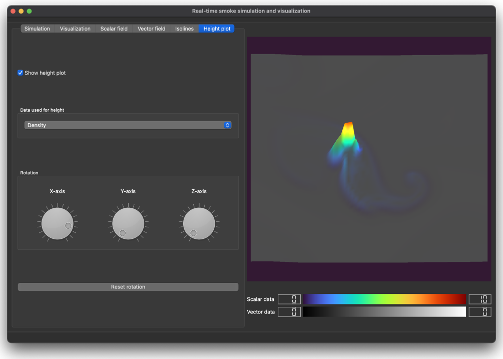
[1]When modifying the shader source codes, you may run into a runtime error caused by an assert (e.g. `ASSERT: "m_uniformLocation* != -1" in file ../Smoke/visualization.cpp`). This is usually caused by a certain input variable or uniform variable directly or indirectly *not* being used, followed by the shader program not being able to find its corresponding location. To (temporarily) disable this check, either comment out the `Q_ASSERT` statement referred to in the error message, or create a Release build (Click on the screen icon above the green 'Run' button).) After completing this subtask, all shader variables should be in use.



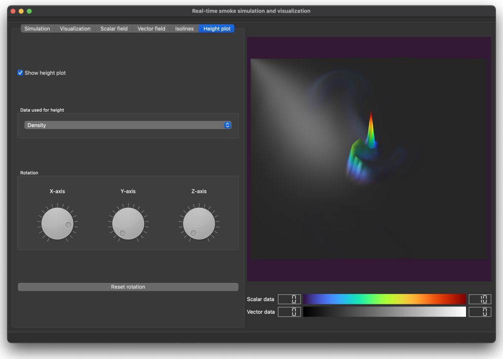
(a) Plain color mapping with Turbo color map.



(b) Gradient magnitude in different directions.



(c) Bivariate color map.



(d) Illumination

Figure 1: Screenshots for Task 2 (b) – Height plots.

- Compute the gradient of the height map via finite differences (in the function `computeNormals` in `visualization.cpp`, code from the prior task may be reused). Check the results by mapping the change magnitude in x- and y-direction to color in vertex and fragment shader via an adequate mapping (see Figure 1b).

- Implement a simple bivariate color map in the shader considering total gradient magnitude in x- and y-direction as well as the height value as follows. The basis color is taken from the height value to color mapping above. Then, the xy gradient magnitude is clamped to $[0, 1]$ and is used to linearly interpolate between this original color for a magnitude of 1, and gray value $(0.3, 0.3, 0.3)$ for a magnitude of 0 (see Figure 1c).

- Implement Gouraud shading (i.e. apply the Phong reflection model in the vertex shader) to improve the perception of structures (see Figure 1d). The material properties are given in `uniform vec4 material` containing, from index 0 to index 3, k_a, k_d, k_s and α.

Task 2 – Isolines (8 points)

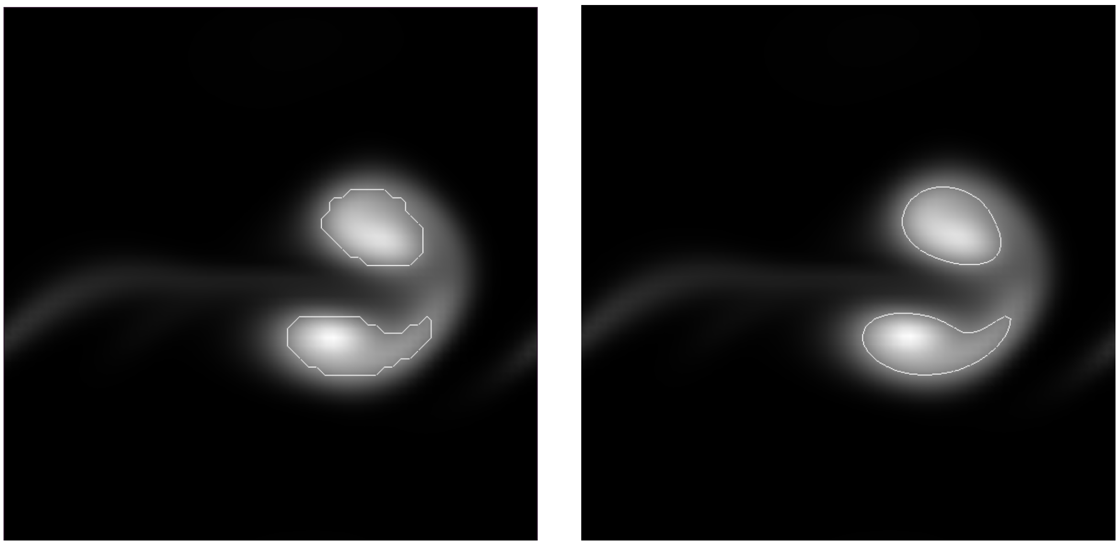
The file `isoline.cpp` contains the framework of an (incomplete) isolines implementation using the marching squares algorithm. The function `drawIsolines` in `visualization.cpp` instantiates one or more `Isolines` classes with the desired parameters, after which the `Isolines` class initializes its `m_vertices` container. The `drawIsolines` function then calls the `vertices()` function on it to retrieve a list of 2D coordinates[2], where each subsequent pair of coordinates form a line.

The implementation follows case and vertex labeling convention of the lecture slides and Wikipedia. It is recommended to first fully implement the non-interpolated version and afterwards the interpolated version.

- For the non-interpolated version: A nested loop is given which iterates over the bottom-left vertex of all squares (or *cells*). For each square, use `m_isolineRho` and the values at each vertex to construct an index for the jump table. The provided jump table is already connected to the 16 cases (note that the interpolated cases are listed first). Complete the implementations of all cases. Non-interpolated means that the start and end coordinates of each lines are exactly in the middle of two vertices. The length of the side of each square is given in `m_cellSideLength`. Case 1 is provided as an example for both the interpolated and non-interpolated versions. Note that not every case uses all parameters. Use the *midpoint decider* **or** the *asymptotic decider* algorithm to resolve ambiguous cases, and make a note of which you have used in your report.
- The implementation of the interpolated version is analogous to the non-interpolated one, except that each case also has parameters for the vertex indices in the `values` container. This allows them to obtain the scalar values corresponding to each vertex from the `values` container, after which linear interpolation can be used with `m_isolineRho`.

To test your implementation, we suggest setting the number of isolines to 1 and the range to $[0.5, 0.5]$ (in the GUI). This should render one isoline with results similar to Figure 2a and Figure 2b. From here on, try setting the range to, e.g., $[0, 1]$ and increase the number of isolines.

[2]The 2D coordinates are stored in a `QVector2D` class. Its elements, accessible as `x` and `y`, correspond respectively to the horizontal and vertical axes.



(a) 1 isoline at density threshold 0.5, no interpolation.

(b) 1 isoline at density threshold 0.5, linear interpolation.

Figure 2: Screenshots for Task 2 (c) – Isolines.