A Streamline Selection Technique for Integrated Scalar and Vector Visualization

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1 Introduction

Scalar and vector field visualization techniques have evolved almost independently. We think integration of scalar and vector visualization is still an interesting topic. For example, many researchers in fluid dynamics simulations still use 2D scalar and vector visualization techniques in one display, to demonstrate the coherency between scalar (e.g., temperature and air pressure) and vector (e.g., air flow) fields; however, it is not easy to understand three dimensional mechanism of fluid dynamics from the 2D visualization results. On the other hand, several visualization works integrate 3D scalar and vector visualization techniques; for example, Treinish et al. reported a visualization system for weather simulation results [1], as combination of 3D scalar and vector visualization techniques. Such integrated 3D visualization systems are useful to understand the three dimensional coherency between scalar and vector fields. We think it is still a research issue to automatically obtain optimal visualization results from such integrated 3D systems.

This poster presents a streamline selection technique for integrated scalar and vector field visualization. The technique visualizes a scalar field by multiple semitransparent isosurfaces, and a vector field by multiple streamline, where the technique adequately selects the streamline considering of reduction of cluttering among the isosurfaces and streamlines.

The technique first selects and renders interesting isosurfaces. It then temporarily generates a lot of streamlines from randomly selected seed points. It evaluates each of the streamlines according to their visibility, and selects the specified number of highly evaluated streamlines. Consequently, the technique visualizes scalar and vector fields simultaneously, by isosurfaces selected from view-nondependent perspective, and streamlines selected from view-dependent perspective.

2 Presented Technique

2.1 Isosurface Selection

First step of the presented technique selects interesting isosurfaces by determining important isovalues in the scalar field. This problem has been well-discussed for transfer function definition for volume rendering [2, 3]. We suppose interesting isosurfaces can be extracted applying the important isovalues determined by such transfer function definition techniques.

Our current implementation generates predefined number of isosurfaces (1 to 3 in the examples of this poster), by automatically determining the isovalues. Then it renders the isosurfaces as semi-transparent surfaces, assigning independent colors (red, green, and blue in the examples of this poster) to each of isosurfaces.

2.2 Streamline Selection

Our technique then temporarily generates a lot of streamlines from randomly selected seed points, and evaluates them based on their information entropy. Information entropy has been already applied in several works on optimal viewpoint selection [4]. Our idea is very similar to these works: it calculates the information entropy E of a streamline as follows:

$$E = -\frac{1}{log_2(m+1)} \sum_{j=0}^{m} \frac{D_j}{L} log_2 \frac{D_j}{L} \quad (1)$$

where m is the number of segments of a streamline, D_j is the length of the j-th segment on the screen, and L is the total length of the streamline in 3D space. Our technique applies the equation to all the streamlines, and sort them according to E. It finally renders the predefined number of streamlines in the sorted order.

Streamline selection is a recent active topic, and there have been several novel works. For example, Li et al. reported an illustrative technique to select streamline on a screen space [5]. Comparing with such existing techniques, our technique tends to render less number of long and informative streamlines.

In addition to calculating the information entropy, our technique considers of following points:

Density control. Our technique often highly evaluates very close streamlines, because they are usually very similar; however, it looks very dense if it renders all such streamlines. Therefore, our technique calculates the minimum distances from several vertices of currently rendering streamline to already rendered streamlines. If at least one of the minimum distances is enough large, the technique renders the current streamline. Otherwise, it cancels to render the current streamline.

Critical points. It is well-known that important phenomena in vector fields are often observed around critical points (e.g., center of vortex), and therefore it is fruitful to generate streamline around the critical points [6]. Our current implementation generates seed points which are enough close to at least one of the critical points, and sorts the streamlines starting from the seed points in the order of E. This poster calls such streamlines as "near-critical streamlines". It then preferentially renders predefined number of the near-critical streamlines, and finally renders non-near-critical streamlines. Our current implementation can distinguish the colors between near-critical and non-near-critical streamlines. Examples in this poster draw near-critical streamlines in red, and the others in black.

Figure 1 shows the effort of density control and critical point extraction. We can observe that streamlines are effectively distributed, and vortex is certainly visualized by red streamlines, in Figure 1(right).

Cluttering with isosurfaces. Since it is not preferable that a lot of streamlines occluded by isosurfaces are rendered, our technique applies a penalty to the occluded streamlines. It determines the occlusion by an isosurface for each segment of a streamline, and calculates the new entropy E' by the following equation:

$$E' = (1 - m_0/m)E + (m_0/m)(1-a)E \quad (2)$$

where m_o is the number of occluded segments, and a is the opacity of an isosurface.

Extending the above idea, the technique calculates the new entropy, if a segment may be occluded by multiple isosurfaces. Suppose that the i-th segment of a streamline ($1 \leq i \leq m$) is occluded by

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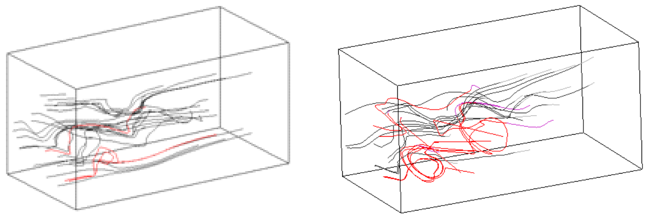

Figure 1: Comparison of streamline generation. (Left) Without density control and critical point extraction. (Right) With density control and critical point extraction.

multiple isosurfaces, and let the opacities of occluding isosurfaces a_1 to a_{n_i}, where n_i is the number of isosurfaces occluding the i-th segment, and the isosurfaces are sorted in the order of their depths. We weight the length of D_i as follows:

$$D_{ij} = (1 - a_j) D_{i(j-1)} \tag{3}$$

where $1 \leq j \leq n_i$, and $D_{i0} = D_i$. The technique calculates the entropy as follows:

$$E = -\frac{1}{log_2(m+1)} \sum_{j=0}^{m} \frac{D_{jn_j}}{L} log_2 \frac{D_{jn_j}}{L} \tag{4}$$

2.3 GUI

In addition to focusing on automatic selection of isosurfaces and streamlines, our current implementation provides GUI to adjust the following parameters: isovalues and opacity of isosurfaces, and number of near-critical and non-near critical streamlines.

3 Example: Visualization of Weather Simulation Results

We applied the presented technique to visualization of weather simulation results, which contain scalar fields of temperature and air pressure, and a vector field of air flow. While visualizing such weather simulation results, we often focus on high- or low- pressure areas, and warm or cold air masses. Such phenomena can be visualized as isosurfaces around local maximum or minimum points of the scalar fields. Also, we often focus on air flow around such high- or low- pressure areas, and warm or cold air masses. Such air flow can be visualized by adequately generated streamlines.

Figure 2 shows an example of integrated visualization of air pressure and air flow obtained from a weather simulation result. The simulation assumes the ground as XY-plane, and Z-coordinate denotes the altitude. In other words, Figure 2 draws the ground near, and the air far. Two isosurfaces denote specific air pressure values which bring high- and low-pressure systems. The result denotes that the air flow revolves around the high- and low-pressure systems. Here the technique randomly generated 500 streamlines and selected 22 of them.

Figure 3 shows a comparison of visualization results while the left result does not consider of occlusion by an isosurface, while the right result considers of the occlusion. It proves that more number of non-occluded streamlines and less number of occluded streamlines are generated in the right result.

4 Conclusion and Future Works

This poster presented a technique for automatic streamline selection technique for integration of scalar and vector field visualization, based on information entropy, density, critical points, and occlusion by isosurfaces. As future works, we would like to extend the technique to time-varying volume data, implement on GPU environment, and carry out subjective evaluations.

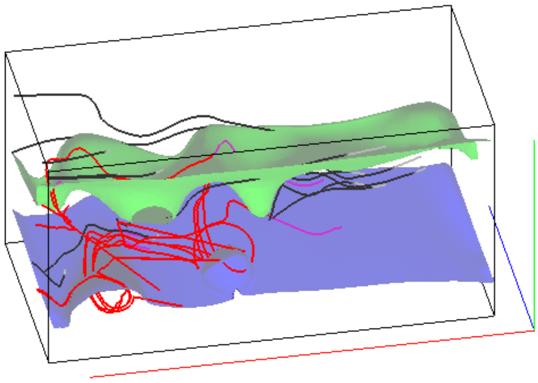

Figure 2: Integrated visualization of air pressure and air flow.

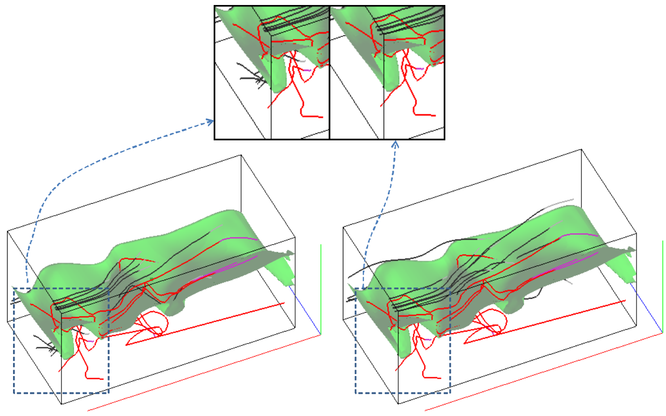

Figure 3: Comparison of consideration of occlusion by isosurfaces. (Left) A result without the consideration of the occlusion. (Right) A result considering of the occlusion.

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