Coordinate Independent Visualization Method for Stress Tensor Field by Using Principal Axis Line

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The physical quantities in the physics problems are written in tensor. The scalar field written in the zeroth-order tensor and the vector field written in the first-order tensor are easily visualized and are implemented on various visualization tools.
On the other hand, in the three-dimensional space, the fields of physical quantities written in the symmetric second-order tensor (e.g., strain or stress in continuum) have the six independent components. For instance, in the conventional visualization method of the stress field, we need the set of six contour maps color-coded by the three normal stresses and the three shear stresses, or the set of the three contour maps color-coded by the three principal stresses (i.e., major, medium, and minor principal stress) and the three line segment maps showing the directions of three principal axes. Therefore, it is almost impossible to intuitively understand the whole second-order tensor field by comparing these several images.
To solve this problem, some topological-based visualization method have been proposed. In these method, a ellipsoid is defined at every point in the analysis domain. The axes of this ellipsoid are parallel to the three principal axes and the length of the axes are scaled by the absolute value of the principal value. Then, these ellipsoids or the tube obtained by connecting glyphs in the longitudinal axis direction are displayed in the analysis domain. However, these method is only effective as long as the all principal values are positive (e.g., diffusion tensor used in a tractography of MRI images). In the case of the stress or strain tensor, since the principal value becomes the negative under compression, these visualization methods cannot show the second-order tensor field correctly.
In this research, we propose the new visualization method and the algorithm to help the correct and intuitive understanding of the second-order symmetric tensor field in three-dimensional space. Here, for the sake of simplicity, we use the stress tensor for the explanation of the outline of the proposed method. In the proposed method, the visualization domain are divided into small domains arranged so as not to overlap with each other. If the constant stress tensor field is given in each small domain, the line segment tangent to the principal axis can be defined in each small domain. When this line segment passes through the boundary of the small domain, we select the line segment direction from the three principal axes direction in the next domain. Here, we select the direction so that the two line segments are connected with each other most smoothly. Then, we draw the next line segment tangent to the selected principal axis. It should be noted here that the selection of the line segment direction is not carried out to connect between the major (medium, minor) principal axes. The line segment is colored according to the principal value associated with the line segment direction. Performing the series of these drawing operations from several start points (called ‘seed’) placed in arbitrary position to three orthogonal principal axis direction, we can draw multiple lines (called ‘principal axis line’) in the visualization domain. These principal axis lines enable to show the six independent components of the second-order symmetric tensor in one figure.
According to these principal axis lines, we can understand the flow and magnitude of the second-order symmetric tensor field. Also, while the contour maps showing the components of the second-order symmetric tensor are completely changed by the rotation of the coordinate system, the principal axis lines given by the proposed method are independent from the rotation of the coordinate system.
In the conference, we will show some examples and will discuss about the application to the dynamic

wave field.

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