Development of visualization tool for the wave propagation data on sphere

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1 Introduction

An analysis of seismic waveform data on Earth surface plays an important role in geophysical research because seismic waves excited by earthquake source propagates various regions inside the Earth and provide us information on physical state of the Earth. In order to visualize such wave data on global area in computer graphics, we have developed a tool for creating a polygon from the scalar/vector data mapped on an unstructured grid in two dimensions. In general, the data on the sphere surface is visualized, for example, by the color contour mapped on the sphere geometry. Our method utilizes the deformation of the polygon coordinate from sphere geometry for representing the wave form. Such a visualization method of wave form is not implemented on commonly used application such as GMT (Generic Mapping Tools). In this paper, we present some details of our employed method to convert the unstructured data to polygon data, and demonstrate visualization result of global seismic wave simulation.

2 Method

We consider the scattered data set a_p ($p=1,2,3\ldots$) defined at spherical coordinate (r,θ_p,ϕ_p) on spherical surface (i.e. $r=$ *constant*). In our tool, this unstructured dataset is interpolated to the data on structured mesh with a grid size of $n_\theta \times n_\phi$. The 2-D uniform mesh defined by ($\theta_i=(i-1)\times\Delta\theta$, $\phi_j=j\times\Delta\phi$) with $\Delta\theta=\pi/(n_\theta-1)$ and $\Delta\phi=2\pi/(n_\phi-1)$ constructs the cell which has center at $\left(i+\frac{1}{2},\, j+\frac{1}{2}\right)$.

We first calculate a weight factor $w_p(i,j)$ of $p-th$ scattered point to the node point at (i,j) by

$$w_p(i,j)=\max((1-|\theta_p-\theta_i|)/\Delta\theta) \times(1-|\phi_p-\phi_i|/\Delta\phi)/(\Delta\theta\Delta\phi),0) \quad , \qquad (1)$$

In Eq. (1), the weights of $p-th$ scattered point $w_p(i,j)$ are distributed to four corners of the cell that includes the point, by the simple first order accuracy scheme (Fig.1 (a)). The node value is obtained as

$$a_{i,j}=\sum_{p\in cells} a_p w_p(i,j)/S^0{}_{i,j} \text{ with } S^0{}_{i,j}=\sum_{p\in cells} w_p(i,j)\,, \qquad (2)$$

where *cells* are four surrounding cells of the node point (i,j). For the node points which have no entry of scattered data (i.e. $S^0{}_{i,j}=0$), the procedure of (2) is skipped. Instead, empty node data are iteratively ($n=0,1,2\ldots$) filled with the averaging of surround nodes by

$$a_{i,j}=\sum_{I,J} a_{I,J}\theta(S^n{}_{I,J})/\sum_{I,J}\theta(S^n{}_{I,J})\,, \qquad (3)$$

and

$$S^{n+1}{}_{i,j}=\sum_{I,J}\theta(S^n{}_{I,J}) \qquad (4)$$

where $(I,J)=(i+1,j)$, $(i-1,j)$, $(i,j+1)$ and $(i,j-1)$, and $\theta(\cdot)$ is a function defined by

$$\theta(x)=\begin{cases}1 & x>0\\ 0 & x=0\end{cases}. \qquad (5)$$

The averaging procedures of (3) are iteratively applied to the empty node points until filling all of node data with $S^n{}_{i,j}\neq 0$.

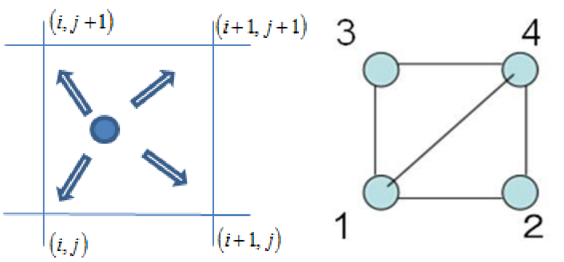
After the mapping process described above, we reduce the mesh size in ϕ direction on a polar region, in order to avoid the concentration of the structured grid around the pole. The reduced coarse mesh points are defined by

$$\Phi_{i,j}=j\times\Delta\Phi(i) \text{ and } \Delta\Phi(i)=2\pi/(n_\Phi(i)-1)\,, \qquad (6)$$

where $n_\Phi(i)=n_\Phi/2^{N(i)}$ and $N(i)=\mathrm{int}(-\log_2\sin(\theta_i))$ for ($1<i<n_\theta$) and $N(1)=N(2)$ and $N(n_\theta)=N(n_\theta-1)$ (Fig 2). The fine grid data are remapped to the coarse one with a linear interpolation. This coarsening scheme leads to 22.0-25.0% of grid size reduction.

Then it is straight forward to create the polygons of sphere shape by dividing the structured grid cells to triangles. In our method, only two types of polygon geometry are taken into account: a division of simple square profile (Fig 1 (b)) and an interface block between fine and coarse grid (Fig 1 (c)).

Finally, the polygon's coordinate on sphere are deformed to represent the scalar/vector data on each node. The scalar $\vec{a}_{i,j}=((a_{i,j})_1,0,0)$ or vector $\vec{a}_{i,j}=((a_{i,j})_1,(a_{i,j})_2,(a_{i,j})_3)$ value on each node is expressed by the displacement of the position from sphere by $(r+(a_{i,j})_1,\theta_i+(a_{i,j})_2,\Phi_{i,j}+(a_{i,j})_3)$.



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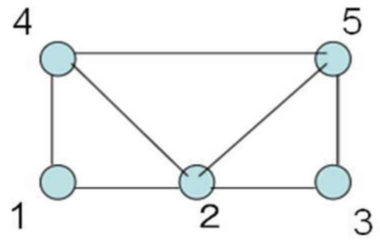
(a) (b)



(c)
Fig. 1 (a) Structured grid mesh and scattered data; (b) Division of normal cell; (c) Division at interface cell

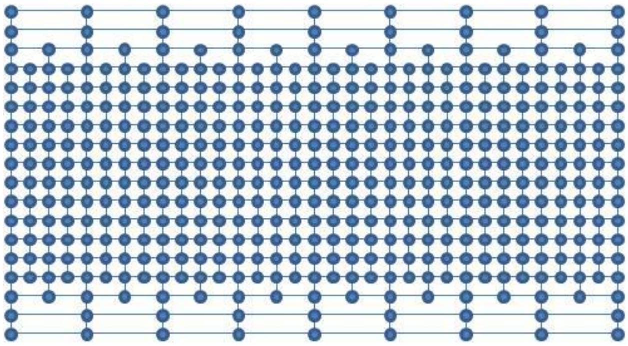


Fig. 2 Example of the reduced grid cell for $(n_\theta, n_\phi) = (16,32)$

3 Result

Here, we demonstrate visualization result by our developed tool for the simulated global seismic wave propagation. This simulation is performed by using the Spectral-Element Method [Komatitsch and Villote, 1998; Komatitsch et al., 2003] for the earthquake, which occurred in Tonga region on Septemebr 10, 1992. The seismic waveform excited by this earthquake is analysed in Butler and Tsuboi (2010). The output data of this simulation is given by unstructured grid mesh. The polygon data given by our tool are visualized by the lay tracing software Pov-ray [1]. The picture of Fig3 shows a snap shot of visualization result. The wave form given by the scalar value on the earth surface is captured from two different points of view. The animation movie of this simulation result is also presented at [2]. From these result, our simple but powerful polygon making tool is found to successfully visualize the wave form on the sphere in the three dimensional representation.

Acknowledgements

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References

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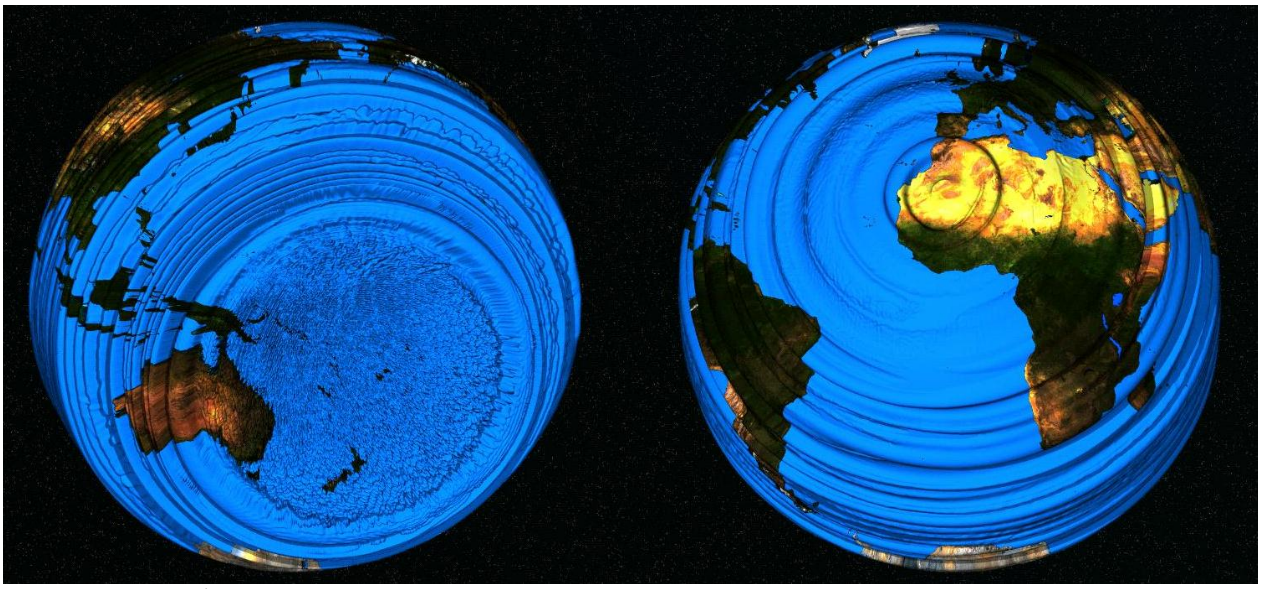

Fig. 3 snapshot of the simulated seismic wave