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Physics of Seismic Wave Propagation Inferred from the 4D Volume Visualization

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Earthquakes are 4D (3D space + time) complicated phenomena which involve the radiation of seismic waves from the earthquake source fault, the propagation through subsurface structure and the amplification on sedimentary layers. In order to investigate physics of seismic wave propagation to predict strong ground motions and take countermeasures against earthquake disasters, it is indispensable to understand the earthquake phenomena correctly and quantitatively. The dense network of strong ground motion station across Japan enables us to compare the observations and result of the simulations. Supercomputers can simulate the seismic wave propagation accurately by solving equations of motion with a high-resolution structural model. As the size of simulations has been larger, the visualization of seismic wavefield has been getting more and more important because output data include a lot of features we have to categorize. The appropriate visualizations are required not only for students of earthquake to comprehend the complex phenomena of the propagation of seismic waves from the hypocenter through heterogeneous structure to the surface of the ground and give intelligible explanations for them but also for the public to raise the awareness of earthquake disaster prevention.

In this study we applied one of the visualization methods called volume rendering for various earthquakes and made animations to explore the effect of subsurface structure on the seismic wavefield. We provided learning tools of the important phenomena of earthquakes such as the radiation of seismic waves, the refraction and reflection of them and the generation and propagation of diffracted and surface waves. The volume rendering can show 3D space at a time by coloring each pixel with proper transparency corresponding to the intensity and space variation of energy. This is one of the advantages of the volume rendering which makes it possible to render waves of small amplitude such as scattered and refracted waves. Since the amplitude of waves in the area far from the source is quite small because of geometrical spreading, we should enhance small-amplitude waves to visualize them clearly. For example, the Mid Niigata Prefecture Earthquake in 2004 raised the amplification of ground motion at basin structures and generated a long-period ground motion which shook high-rise buildings. The volume rendering animation of this earthquake showed 1) the basin structure beneath Chuetsu region generated the surface wave and 2) it propagated along the surface layer slowly to the Kanto Plain and 3) the basin structure of the Kanto Plain amplified it and 4) ground motion lingered because the waves were trapped in the basin.

The study concluded that the 4D volume visualization reconstructed a variety of phenomena concerning earthquakes well and it is useful to comprehend the complex phenomena and to give adequate explanations for them.

Keywords: earthquake, visualization, simulation, volume rendering