Stability analysis of finite difference operators for computing synthetic seismograms with fluid-solid boundary condition

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The question of how to include fluid and solid media in the time domain finite difference (FD) scheme efficiently is unsolved problem. Some researches use staggered grid scheme with setting shear modulus as zero to express fluid media and fluid-solid boundary, which is proved to be rigorous based on the heterogeneous formulation (Okamoto and Takenaka, 2005, Zishin),
and spectral element method which is based on weak form formulation (Komatitsch et al, 2000, Geophysics). The displacement only FD scheme is thought to be inaccurate and instable (see Vireux, 1986).

In this research, we use pressures as independent variables in the fluid region and displacements in the solid region, based on weak form formulation (see Geller and Ohminato, 1994). We use time domain finite difference schemes (2nd order time and space) in both solid and fluid region (Takeuchi and Geller, 2000). These regions are connected by boundary operators. The boundary operators sometimes causes instability because its poor implementation. Such instability can be avoided by using temporal staggering by half size of the time step (Delta t/2) of the variables in solid region and fluid region.We rewrite time domain operators to the matrix operators for evaluation of stability. These matrix operators should be Hermitian for the stability (Mizutani and Geller, 2005, EPSU Joing Meeting).

The figure shows the simple example of calcuration. The upper layer is the fluid and the lower layer is solid. The compressional type source is used in the fluid region. The right figure is the close up view of the result. The clear diffracted waves can be seen.

In the presentation, we show the details of numerical schemes and theoretical analysis of stability conditions.