Report 13

New Damping Absorbing Boundary Conditions

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ABSTRACT

A simple and improved damping absorbing boundary condition (ABC) is presented that is noticeably more efficient than the ABC’s in the UTAM codes. This claim is verified for tests with 3-D acoustic finite-difference simulations, but this new ABC should also be effective for elastic and viscoelastic wave-equation modeling.

INTRODUCTION

For finite-difference wave-equation forward modeling and reverse-time migration, the ABC may affect the total cost and the quality of results. For the UTAM codes we have used a simple damped ABC, where its effectiveness leaves much to be desired, especially in 3-D. Thus we devoted some time to discover a more effective ABC. We have found that a new damping function, which is first-order smooth at the damping boundary, and performs more effectively as an ABC for 3-D acoustic models. Tests also show that simultaneously damping the particle velocity and stress variables, rather than damping the particle velocity only, leads to significantly fewer artificial reflections from the sides of the model. The damping factor 0.80 is found to be an optimum value for the new damping algorithm with a damping width of 20 grid points.
TWO DIFFERENT DAMPING FUNCTIONS

The damping function below is used in our current UTAM’s codes as an absorbing boundary condition:

\[ f(i) = \exp((i - 1) \times \log(ass)/ndamp), \]  

(13.1)

where "f(i)" is the damping at the ith grid point in the damping boundary, "ass" is the damping factor, and "ndamp" is the width of damping zone (unit grid point). The solid line in Figure 13.1 shows a plot of the damping factors vs grid numbers. It should be noticed that the first-order differential of this damping function is not equal to zero at the damping boundary. We shall call this damping function the old damping function.

We also can use another kind of damping function denoted as:

\[ f(i) = \exp((i - 1)^2 \times \log(ass)/ndamp^2), \]  

(13.2)

The dashed line in Figure 13.1 shows the damping curve, where the first-order differential of this damping function is equal to zero at the damping boundary. Thus this damping function is first-order smooth at the damping boundary and we shall refer to it as the new damping function.

NUMERICAL TESTS

First we test two different implementations of the damping functions. The model is a 3-D homogeneous acoustic model with a P velocity equal to 4750 m/s. The model size is 191 x 291 x 162 (nx x ny x nz), which includes a 20-grid thick damping zone along each boundary and a grid spacing of 50 m. An explosive point source with a peak source frequency of 10 Hz is placed at the grid point coordinate (95, 95, 100), and a receiver is placed at the grid point coordinate (95, 145, 40) which records the vertical particle velocity. Figure 13.2 displays the artificial reflections from the boundary, with the solid (dashed) line denoting the results from damping particle velocity only (simultaneously damping particle velocity and stress). It is found that significantly weaker artificial reflections are generated if both velocity and stress variables are simultaneously damped, rather than damping particle velocity only.
Figure 13.3 shows the artificial reflections from the boundary for different values of the old damping factor ‘ass’. It is found that the artificial reflection first decreases then increases when decreasing the damping factor ‘ass’ from 0.95 to 0.80. The optimum value of ‘ass’ is found to be 0.90.

Figure 13.4 shows the artificial reflections using the new damping function. The values of the damping factor decrease from 0.95 to 0.60. The optimum value of the damping factor is smaller than that of the old damping function, and many fewer artificial reflections are generated for the same sized damping zone. The value $ass = 0.80$ provides a very good damping effect for a damping width of 20 grid points.

**CONCLUSIONS**

Some numerical tests on 3-D acoustic modeling show that the new damping function provides a more effective absorbing boundary condition. It is found that simultaneously damping both types of field variables is better than just damping the particle velocity variables. The optimum value of the damping factor is 0.80 for a damping width of 20 grid points using the new damping function. The tests are performed for the 3-D acoustic case, but the new damping function should also be useful for elastic and viscoelastic modeling. Our limited number of test empirically suggest no stability problems with this new ABC.
Figure 13.1: Comparison between old damping curve (solid line) and new damping curve (dash line). Both are continuous at the damping boundary, but the new damping function is first-order smooth at the damping boundary.

Figure 13.2: Comparison between two damping schemes: (1) damping particle velocity variables only (solid line), (2) damping particle velocity and stress variables simultaneously (dash line). The second scheme provides a more effective ABC. Here the direct wave is not included.
Figure 13.3: Artificial reflections using the old damping function with a damping factor 'ass' equal to, from top to bottom, (1) 0.95, (2) 0.90, (3) 0.85, and (4) 0.80 and a 20 point wide region for damping. The optimum value of 'ass' is about 0.90.
Figure 13.4: Artificial reflections using the new damping function with a damping factor 'ass' equal to, from top to bottom, (1) 0.95, (2) 0.80, (3) 0.60 for a damping region with a width of 20 grid points. The optimum value of 'ass' is about 0.80.