Wave equation event migration

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Interpreters often find themselves studying a particular seismic event and asking themselves, "Where did that event end up on the migrated section?" Answers to similar questions would be equally useful: *Is this event a diffraction? If so, how well does my velocity function focus it? Does migration fully separate these overlapping events? This event seems much stronger after migration; where did the energy come from?* The difficulty in answering questions like the above is that one can never be sure how much migration has altered the appearance of an event. The human eyeball is at a disadvantage with conventional displays because it is naturally drawn to high amplitudes and striking, similar patterns. Ray-trace structural modeling has always made a correspondence between original and migrated events easy to see by oversimplifying the physics involved. By ray tracing an interpreter can see what seismic event results geometrically from a digitized guess of the geologic structure, or the reverse. But ray tracing omits all of the effects of adding amplitude information. Point and edge diffractions must be treated as special cases. The effects of superimposing two events is entirely lost. Numerous small events are necessarily avoided. And the iterative nature of the procedure makes it tedious and time consuming. Imagine though that we could add a little colored ink to the section migrated or diffracted by the wave equation.

We can imagine an computer tool which would make it possible for the interpreter to answer his questions very easily. The user would be able to take a digitizer or light pen and outline a seismic event on a time or depth section. The computer would highlight this event in color (say red on black), diffract or migrate, and then show the equivalent event in the other domain, shading the traces where the event contributes most. One could make do with two colors--black for the ordinary energy and increasing amounts of red for increasing contributions of the outlined event.

With this object in mind we can now construct an algorithm. First we migrate (or diffract) the original section and save the results. Next, we remove the portion of the data that the user has outlined and fill it in as though it were missing data. One procedure seems particularly reasonable for this step. Transform the abbreviated section to the slant-stack domain (as described in the article on signal/noise separation with slant stacks and migration), keep samples with high amplitude envelopes, diminish those with low amplitude envelopes, and transform back. Substitute the now filled-in region for the deleted portion of the original section. Iterate if necessary. If the outlined region is geologically or statistically independent of the surrounding data, then the filled-in portion will not resemble the major deleted event. The filled-in data will represent background geology and noise which extend into the surrounding regions and which are presumably not of interest. Now migrate the revised section and subtract from the original migrated section. The difference represents the contribution of the deleted event. Fit an analytic envelope to this section of differences as well as to the original section. Calculate the contribution of the event at every sample as the ratio of the differences envelope to the data envelope. Square the ratio to get the percentage of contributed energy and shade the migrated traces where the ratio is high. By only migrating windows of the section one can keep the expense small. The original migration of the section need only be done once.

A user should be able to spot subtle contributions to the outlined event when the migrated or diffracted section is highlighted with color. The human eye correlates patterns of color very easily. Instead of receiving a migrated section and guessing at the changes, an interpreter should be able to see the movement of energy in detail.