Common datuming approaches, like the Kirchhoff or finite difference methods, require reasonable sampling of the sources and receivers. This becomes a serious limitation for datuming data acquired using 3D conventional land acquisition layouts, because of the typical sparse spacing of either the sources or receivers. To combat that, we extend Alkhalifah and Bagiani’s (2006) straight ray datuming (SRD) to handle 3D acquisition geometries. As in the 2D case, 3D SRD is based on straight-rays assumption above and below the datum with Snell’s law honoured in between. This allows for the application of SRD to common shot gathers in one operation (no need to sort the data to common receivers). Similarly, it can be applied to common receiver gathers without the need to sort the data back to common shot gathers. This feature allows for more flexibility in acquisition as it requires, unlike in the conventional case, either the sources or receivers to have a complete fine coverage of the area. In addition, SRD does not require detail description of the near surface velocity model, information from refraction static or any other commonly used method to obtain near surface time shift suffice.

As well as carrying out redatuming, SRD can be used to map spatially irregularly sampled data at the acquisition surface into regularly sampled data at the datum. In fact, since the operation is a partial migration, it suppresses diffractions generated from inhomogeneities above datum. The computational cost of applying 3D SRD is larger than static corrections, but because of the limited spatial extension and analytical formulation, is far less than Kirchhoff re-datuming.

Static corrections are computed and applied to surface seismic data to compensate for the effects of topography and lateral velocity variations in the near surface (Cox, 1999). Their computation is based on the assumption of ray vertical incidence and their application is a simple time shift applied to an entire trace. As a result of ignoring ray bending and other wave phenomena, static corrections, in their conventional form, have serious limitations (Shivelman and Canning, 1988).

Wave-equation datuming has emerged as an alternative to static corrections to address situations in which the assumptions of conventional static corrections are not valid. Berryhill (1979) derived a computationally efficient form of the Kirchhoff integral for redatuming of stacked data, which was then extended by the same author to prestack data (Berryhill, 1984). Shivelman and Canning (1988) pointed out that Berryhill’s scheme is computationally efficient only for small extrapolation intervals, for which static corrections are often a valid approximation, and proposed a scheme based on the asymptotics of the Kirchhoff integral solution of the 2D scalar wave equation. However, datuming has suffered from the high cost of application and the requirement that a well defined velocity model of the near surface be available. Also, in 3D, conventional datuming requires reasonable sampling of the sources and receivers, which becomes a serious limitation for datuming data acquired using conventional 3D land acquisition layouts, because of the typically sparse sampling of the either the sources or receivers.

The 3D SRD introduced here fills the gap between the simple but often inappropriate surface-consistent static correction and the more rigorous but computationally expen-
sive Kirchhoff prestack redatuming. In addition to the benefits of the application in land seismic surveys in the presence of high-velocity near-surface layers, SRD is expected to be effective in handling 3D acquisition as it is usually possible to have the either the sources or receivers well sampled.

**SRD concept**

A Kirchhoff implementation requires the derivation of a summation trajectory (or impulse response) in the input data space. The features of SRD make its derivation a challenging task. Some of these features are: both SRD input and output domains are prestack, irregular topography of input data, and possibly different velocities at the source and receiver sides. We derive the SRD kinematics using geometrical optics argument, as Figure 1 schematizes the rays involved in the derivation of the SRD impulse response.

SRD rays are selected to satisfy Snell’s law at the datum interface, and consequently, the impulse response depends on the velocity below the datum (medium velocity), which can be initially set to an expected average velocity. The application of Snell’s law at the interface allows the reduction of the surface integral needed in Kirchhoff datuming (usually applied as two 3D operations to each of the common source and receiver data) to a surface integral applied once (stationary phase approximation). The trajectory of the summation operator for the Kirchhoff implementation depends on the offset, elevation of the source and receiver, and the velocity of the weathering layer under each source and receiver.

**Impulse response**

To test the 3D SRD, we first investigate the impulse response on a common shot gather. Figure 2 shows the source and receiver configuration of a common shot gather that contains a pulse located at 1 second, 500 m x-direction offset and 250 m y-direction offset inserted into the SRD to generate the impulse response shown in Figure 3. The datum is at depth 200 m from surface.

Figure 2 A schematic plot showing the location of the source and receivers of a common shot gather containing a pulse located at 1 second, 500 m x-direction offset and 250 m y-direction offset inserted into the SRD to generate the impulse response shown in Figure 3. The datum is at depth 200 m from surface.

Figure 3 A horizontal slice of the impulse response at time 0.71 seconds of the SRD process applied to the common shot with a pulse at 500 m x-offset and 250 m y-offset, as described in Figure 2. The apex of the impulse response appears at time 0.8 second, 538 m x-offset and 271 m y-offset.

Figure 4 A velocity model with two horizontal interfaces, a weathering layer, and a 2000 m/s velocity main layer. The weathering layer includes a high-velocity (4000 m/s) intrusion. The source is located at 1000 meters with receivers stretching from 200 m to 1800 m for the examples in Figures 5 and 6.
expected asymmetry in all directions despite that the velocities are laterally invariant (source and receiver velocities are the same). The asymmetry is caused by the common shot domain nature of the implementation. Also, the extension of the operator in the \(x\)-direction exceeds that in the \(y\)-direction considering that the pulse is located at 500 m \(x\)-offset and 250 m \(y\)-offset. The apex of the response is, as Figure 3 indicates, slightly shifted location wise from the pulse location. This is expected as an inherent nature of datum to move energy closer to the source as we datum downward (or the source receiver offset becomes smaller).

**Testing the 3D SRD**

In the following we show a simple test that is devoted to emphasizing the difference between SRD and static correction, especially since the application of static correction is dominant in 3D land data. Figure 4 shows a a vertical slice of a 3D velocity model composed of two layers (in addition to the weathering layer). The first layer and second layer velocities are respectively, 2000 m/s and 3500 m/s. For this test, the topography is flat, and the weathering layer (directly below), with a velocity of 1500 m/s, has a flat bottom. The weathering layer includes a high-velocity (4000 m/s) intrusion near the surface. We use the actual velocity model to derive the static corrections and the SRD velocities. The velocity in the direction normal to the slice in Figure 4 does not vary (2.5 D).

The high-velocity intrusion in Figure 4 is expected to alter reflections dramatically at certain (negative) offsets for a source located at 1000 m. Figure 5 shows a vertical and horizontal slice of a 3D common shot gather after applying static correction (left) and SRD (right). Clearly, the results of SRD are better than the static shift. The moveout of the SRD is more accurate since it takes the non-vertical ray path into consideration, and the moveout is cleaner as the SRD in its Kirchhoff implementation suppresses diffractions. In addi-

**Figure 5** A vertical and horizontal slice of the 3D common shot gather after static correction (left) and SRD (right). Arrows point to the difference in quality and in moveout time. The blue object corresponds to the location of the high velocity intrusion.

**Figure 6** Left: A vertical slice of a 3D velocity model containing a complex weathering and a horizontal reflector at 400 meters depth. The arrow points to a column of sharp velocity low. Right: A vertical slice of the 3D stacked section corresponding to the velocity model slice for the area given by the dashed box after conventional processing of (a) the original data, (b) after static shift, and (c) after SRD both down to 150 m.
tion, the difference in quality is apparent here as most of the diffractions associated with the shallow inhomogeneity have been suppressed in the SRD result.

**Synthetic test**

Using a 3D velocity model reminiscent of the weathering layer in the Arabian Peninsula Figure 6 (left) displays a vertical slice of it, we generate 3D synthetic data in which a vertical slice of the stacked data after conventional processing is shown in Figure 6a. Clearly, the horizontal interface in at 400 m in the model is no longer horizontal due to the complexity of the weathering layer, especially the low velocity column given by the arrow in Figure 6. Figure 6 also shows the same stacked slice after static correction (b), and 3D SRD (c) to a datum 150 m below surface. Though both results are not perfect, the SRD section has a better representation of the interface than the static shift result.

**Conclusion**

The 3D SRD, which is an extension of the 2D version, with an either common shot or common receiver implementation, allows for flexibility in handling 3D land data. It is far more efficient than conventional datuming since it requires the application of a 2D operator once. Also, 3D SRD, like its 2D counterpart, provides better results than static correction with less near surface diffractions, at a modest increase in the cost. Unlike conventional datuming, it only requires a single velocity above datum for each location. Such a velocity can be easily calculated from conventional static estimation, like refraction statics.

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**References**


