

CLAIMS

1. A computer system that generates an image of a subterranean formation, the computer system comprising:
 - 5 one or more processors;
 - one or more data-storage devices; and
 - a deghosting routine stored in the one or more data-storage devices and executed by the one or more processors to perform the operations comprising:
 - transforming wavefield data generated by one or more receivers of a data
10 acquisition surface located in a body of water above the subterranean formation from a space-time domain to a spectral domain to form a scattered wavefield matrix in the spectral domain;
 - computing a deghosted wavefield matrix at zero depth from the scattered wavefield matrix;
 - 15 iteratively computing a deghosted wavefield matrix that minimizes a cost functional formed from a multiplicative regularization factor and a matrix norm of a residue matrix, each element of the residue matrix is a difference between an element of the scattered wavefield matrix and an element of the deghosted wavefield matrix adjusted to approximate a corresponding element of the
20 scattered wavefield matrix; and
 - generating an image of the subterranean formation using at least in part the deghosted wavefield matrix, the image revealing structural information about the subterranean formation without contamination from ghost reflections.
- 25 2. The computer system of claim 1, wherein transforming the wavefield data from the space-time domain to the spectral domain further comprises:
 - applying a first spectral domain transform to transform the wavefield from the space-time domain to a space-frequency domain; and

applying a second spectral domain transform to transform the wavefield from the space-frequency domain to a wavenumber-frequency domain, wherein the wavenumber-frequency domain is the spectral domain.

- 5 3. The computer system of claim 1, wherein iteratively computing the deghosted wavefield matrix further comprises:

for each iteration:

computing cubic equation coefficients associated with a cubic equation that represents a minimization of the cost functional;

- 10 computing a real-valued root of the cubic equation;

computing a conjugate gradient direction; and

updating the deghosted wavefield associated with each receiver, based on the real-valued root multiplied by the conjugate gradient direction.

- 15 4. The computer system of claim 3, wherein computing the cubic coefficients associated with the cubic equation, further comprises

for each receiver:

computing a preconditioned gradient;

- 20 computing the conjugate gradient direction as a function of the preconditioned gradient; and

iteratively computing coefficients that in combinations form the cubic equation coefficients.

- 25 5. The computer system of claim 4, wherein the preconditioned gradient further comprises a Jacobi preconditioner gradient operator.

6. The computer system of claim 4, wherein the conjugate gradient direction further comprises a Polak-Ribiere conjugate gradient direction.

7. The computer system of claim 4, wherein the conjugate gradient direction further comprises a Fletcher-Reeves conjugate gradient direction.

8. The computer system of claim 4, wherein the conjugate gradient direction
5 further comprises a Hestenes-Stiefel conjugate gradient direction.

9. The computer system of claim 1, wherein the routine further comprises transforming the deghosted wavefield matrix in the spectral domain to a deghosted wavefield matrix in the space-time domain.

10

10. The computer system of claim 1, wherein the cost functional further comprises a real-valued, least-squares-based functional of the residue matrix multiplied by the multiplicative regularization factor, wherein parameters of the multiplicative regularization factor are not obtained from experimental tuning.

15

11. In a process that generates an image of a subterranean formation located beneath a body of water using marine seismic techniques in which a source is activated in the body of water above the subterranean formation and receivers located in the body of water detect wavefield responses from the subterranean formation and record the
20 wavefield responses as recorded wavefield data in a data-storage device, the specific improvement comprising:

transforming the recorded wavefield data generated by each receiver from a space-time domain to a spectral domain to form a scattered wavefield matrix in the spectral domain;

25 computing a deghosted wavefield matrix at zero depth from the scattered wavefield matrix;

computing a deghosted wavefield matrix that minimizes a cost functional formed from a multiplicative regularization factor and a matrix norm of a residue matrix, each element of the residue matrix is a difference between an element of the scattered

wavefield matrix and an element of the deghosted wavefield matrix adjusted to approximate a corresponding element of the scattered wavefield matrix;

generating an image of the subterranean formation using at least in part the deghosted wavefield matrix, thereby revealing structural information about the subterranean formation in the image without contamination from ghost reflections.

12. The process of claim 11, wherein transforming the wavefield data from the space-time domain to the spectral domain further comprises:

transforming the wavefield from the space-time domain to a space-frequency domain; and

transforming the wavefield from the space-frequency domain to the spectral domain.

13. The process of claim 11, wherein computing the deghosted wavefield matrix further comprises:

iteratively computing cubic equation coefficients associated with a cubic equation that represents a minimization of the cost functional;

iteratively computing a real-valued root of the cubic equation;

iteratively computing a conjugate gradient direction; and

iteratively updating the deghosted wavefield associated with each receiver, based on the real-valued root multiplied by the conjugate gradient direction.

14. The process of claim 13, wherein computing the cubic coefficients associated with the cubic equation, further comprises

for each receiver:

computing a preconditioned gradient;

computing the conjugate gradient direction as a function of the preconditioned gradient; and

iteratively computing coefficients that in combinations form the cubic equation coefficients.

15. The process of claim 14, wherein the preconditioned gradient further comprises a Jacobi preconditioner gradient operator.
- 5 16. The process of claim 11 further comprises transforming the deghosted wavefield matrix in the spectral domain to a deghosted wavefield matrix in the space-time domain.
17. The process of claim 11, wherein the cost functional further comprises a real-valued, least-squares-based functional of the residue matrix multiplied by the
10 multiplicative regularization factor, wherein parameters of the multiplicative regularization factor are not obtained from experimental tuning.
18. A non-transitory computer-readable medium having machine-readable instructions encoded thereon for enabling one or more processors to generate an image
15 of a subterranean formation by performing operations comprising:
- storing wavefield data in a data-storage device, the recorded wavefield data generated by one or more receivers located in a body of water above a subterranean formation in response to acoustic energy generated by a source located in the body of water;
 - 20 transforming the recorded wavefield data from a space-time domain to a spectral domain to form a scattered wavefield matrix in the spectral domain;
 - iteratively computing a deghosted wavefield matrix that minimizes a cost functional based on a matrix norm of a residue matrix, each element of the residue matrix is a difference between an element of the scattered wavefield matrix and an
25 element of the deghosted wavefield matrix adjusted to approximate a corresponding element of the scattered wavefield matrix; and
 - generating an image of the subterranean formation using at least in part the deghosted wavefield matrix, the image revealing structural information about the subterranean formation without contamination from ghost reflections.

30

19. The medium of claim 18, wherein the machine-readable instructions further comprise enabling the one or more processors to perform the operation of transforming the wavefield data from a space-time domain to a spectral domain.
- 5 20. The medium of claim 18, wherein the cost functional further comprises a least-squares-based functional of the residue matrix multiplied by a multiplicative regularization factor in a spectral domain.