

CLAIMS

1. A method for filtering seismic data using one or more programmable computers programmed to at least perform the operations of:
 - 5 receiving pressure data and velocity data generated by one or more multi-component sensors of one or more streamers towed by a survey vessel;
initializing values of a filtered wavefield to zero;
for a number of iterations,
applying one or more filters to the pressure data and velocity data to
10 generate a first filtered wavefield;
applying singular value decomposition ("SVD") to the first filtered wavefield to generate an extracted wavefield;
updating the filtered wavefield based on the extracted wavefield to reduce noise in the filtered wavefield;
15 applying SVD to the pressure data and the velocity data to generate corresponding extracted pressure data and extracted velocity data;
adjusting the pressure and velocity data based on extracted pressure data and extracted velocity data; and
storing the filtered wavefield in one or more computer-readable media.
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2. The method of claim 1, further comprising for the number of iterations,
applying the one or more filters to the pressure data and velocity data to generate the filtered wavefield in the frequency-wavenumber domain; and
applying SVD to the filtered wavefield to generate the extracted wavefield in the
25 space-time domain.
3. The method of claim 1, wherein adjusting the pressure and velocity data further comprises:
 - 30 subtracting the extracted pressure data from the pressure data; and
subtracting the extracted velocity data from the velocity data.

4. The method of claim 1, further comprising performing a dip search on one or more of the pressure and velocity data with dip values between $-1/c$ and $1/c$, where c represents the acoustic wave propagation velocity in water and the dip value.

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5. The method of claim 1, wherein applying SVD to one of the first filtered wavefield, the pressure data, and the velocity data further comprises:

for each incremental advance of a data window through one of the first filtered wavefield, the pressure data, and the velocity data,

10 collecting a subset of data within the data window;

horizontally aligning the data according to a dip value of a central sample in the data window;

applying SVD to the data within the data window to generate singular values;

15 sorting the singular values from largest to smallest; and

computing an eigenimage that corresponds to the largest singular value;

and

combining the eigenimages for each incremental advance of the data window to form one of the extracted wavefield, the extracted pressure data, and the extract velocity

20 data.

6. The method of claim 1, further comprises receiving pressure data and velocity data and generating the filtered wavefield with reduced noise in near real time on board a survey vessel.

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7. The method of claim 1, wherein the number of iterations is user specified.

8. The method of claim 1, wherein updating the filtered wavefield based on the extracted wavefield further comprises adding the extracted wavefield to the filtered

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wavefield.

9. A computer system for filtering and reducing noise in seismic data, the computer system comprising:
- one or more processors;
 - 5 one or more data-storage devices; and
 - a routine stored in one or more of the one or more data-storage devices and executed by the one or more processors, the routine directed to:
 - receiving pressure data and velocity data generated by one or more multi-component sensors of one or more streamers towed by a survey vessel;
 - 10 initializing values of a filtered wavefield to zero;
 - for a number of iterations,
 - applying one or more filters to the pressure data and velocity data to generate a first filtered wavefield;
 - applying singular value decomposition ("SVD") to the first
 - 15 filtered wavefield to generate an extracted wavefield;
 - updating the filtered wavefield based on the extracted wavefield to reduce noise in the filter wavefield;
 - applying SVD to the pressure data and the velocity data to generate corresponding extracted pressure data and extracted velocity
 - 20 data;
 - adjusting the pressure and velocity data based on extracted pressure data and extracted velocity; and
 - storing the filtered wavefield in the one or more computer-readable media.
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10. The system of claim 9, further comprising for the number of iterations,
- applying the one or more filters to the pressure data and velocity data to generate the filtered wavefield in the frequency-wavenumber domain; and
 - applying SVD to the filtered wavefield to generate the extracted wavefield in the
 - 30 space-time domain.

11. The system of claim 9, wherein adjusting the pressure and velocity data further comprises:
- subtracting the extracted pressure data from the pressure data; and
 - 5 subtracting the extracted velocity data from the velocity data.
12. The system of claim 9, further comprises performing a dip search on one or more of the pressure and velocity data with dip values between $-1/c$ and $1/c$, where c represents the acoustic wave propagation velocity in water and the dip value.
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13. The system of claim 9, wherein applying SVD to one of the first filtered wavefield, the pressure data, and the velocity data further comprises:
- for each incremental advance of a data window through one of the first filtered wavefield, the pressure data, and the velocity data,
 - 15 collecting a subset of data within the data window;
 - horizontally aligning the data according to a dip value of a central sample in the data window;
 - applying SVD to the data within the data window to generate singular values;
 - 20 sorting the singular values from largest to smallest; and
 - computing an eigenimage that corresponds to the largest singular value;
 - and
 - combining the eigenimages for each incremental advance of the data window to form one of the extracted wavefield, the extracted pressure data, and the extract velocity
 - 25 data.
14. The system of claim 9, further comprises receiving pressure data and velocity data and generating the filtered wavefield with reduced noise in near real time on board a survey vessel.

15. The system of claim 9, wherein the number of iterations is user specified.
16. The system of claim 9, wherein updating the filtered wavefield based on the
5 extracted wavefield further comprises adding the extracted wavefield to the filtered wavefield.
17. A non-transitory computer-readable medium having machine-readable
10 instructions that determine structural information about a subterranean formation encoded thereon for enabling one or more processors of a computer system to perform the operations of:
- receiving a set of wavefields;
 - initializing values of a filtered wavefield to zero;
 - for a number of iterations,
15 performing a dip search on a wavefield in the set of wavefields to generate one or more dip values;
 - applying singular value decomposition ("SVD") to the wavefield to generate an extracted wavefield based on the one or more dip values;
 - adding the extracted wavefield to the filtered wavefield to update the
20 filtered wavefield, reducing noise in the filtered wavefield;
 - subtracting the extracted wavefield from each wavefield in the set of wavefields; and
 - generating an image of the subterranean formation using at least in part
the filtered wavefield, the image revealing structural information about the
25 subterranean formation.
18. The medium of claim 17, wherein performing the dip search on the wavefield further comprises determining dip values between $-1/c$ and $1/c$, where c represents the acoustic wave propagation velocity in water and the dip value.

19. The medium of claim 17, wherein applying SVD to the wavefield further comprises:
- for each incremental advance of a data window through the wavefield,
 - 5 collecting a subset of wavefield data within the data window;
 - horizontally aligning the wavefield data according to a dip value of a central sample in the data window;
 - applying SVD to wavefield data within the data window;
 - sorting the singular values from largest to smallest; and
 - 10 computing an eigenimage that corresponds to the largest singular value;
 - and combining the eigenimages for each incremental advance of the data window to form the extracted wavefield.
20. The medium of claim 17, further comprises receiving the set of wavefields and
- 15 generating the filtered wavefield with reduced noise in near real time on board a survey vessel.
21. The medium of claim 17, wherein the number of iterations is user specified.
- 20 22. A method for generating a geophysical data product, the method comprising:
- receiving pressure data and velocity data generated by one or more multi-
 - component sensors of one or more streamers towed by a survey vessel; and
 - processing the seismic data using a programmable computer that is programmed to generate the geophysical data product, wherein the processing includes:
- 25 initializing values of a filtered wavefield to zero;
 - for a number of iterations,
 - applying one or more filters to the pressure data and velocity data to generate a first filtered wavefield;
 - applying singular value decomposition ("SVD") to the first
 - 30 filtered wavefield to generate an extracted wavefield;

updating the filtered wavefield based on the extracted wavefield
to reduce noise in the filtered wavefield;

applying SVD to the pressure data and the velocity data to
generate corresponding extracted pressure data and extracted velocity
data;

adjusting the pressure and velocity data based on extracted
pressure data and extracted velocity data; and

storing the filtered wavefield in one or more computer-readable
media.

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23. The method of claim 22, further comprising for the number of iterations,
applying the one or more filters to the pressure data and velocity data to generate
the filtered wavefield in the frequency-wavenumber domain; and

applying SVD to the filtered wavefield to generate the extracted wavefield in the
space-time domain.

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24. The method of claim 22, wherein adjusting the pressure and velocity data further
comprises:

subtracting the extracted pressure data from the pressure data; and

subtracting the extracted velocity data from the velocity data.

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25. The method of claim 22, further comprises performing a dip search on one or
more of the pressure and velocity data with dip values between $-1/c$ and $1/c$, where c
represents the acoustic wave propagation velocity in water and the dip value.

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26. The method of claim 22, wherein applying SVD to one of the first filtered
wavefield, the pressure data, and the velocity data further comprises:

for each incremental advance of a data window through one of the first filtered
wavefield, the pressure data, and the velocity data,

collecting a subset of data within the data window;

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horizontally aligning the data according to a dip value of a central sample in the data window;

applying SVD to the wavefield data within the data window to generate singular values;

5 sorting the singular values from largest to smallest; and

 computing an eigenimage that corresponds to the largest singular value; and

 combining the eigenimages for each incremental advance of the data window to form one of the extracted wavefield, the extracted pressure data, and the extract velocity data.

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27. The method of claim 22, wherein the number of iterations is user specified.