Claims

1. An apparatus for encoding a speech signal by determining a codebook vector of a speech coding algorithm, wherein the apparatus comprises:

a matrix determiner (110) for determining an autocorrelation matrix R, and

a codebook vector determiner (120) for determining the codebook vector depending on the autocorrelation matrix R,

wherein the matrix determiner (110) is configured to determine the autocorrelation matrix R by determining vector coefficients of a vector r, wherein the autocorrelation matrix R comprises a plurality of rows and a plurality of columns, wherein the vector r indicates one of the columns or one of the rows of the autocorrelation matrix R, wherein

$R(i, j) = r(|i-j|)$,

wherein $R(i, j)$ indicates the coefficients of the autocorrelation matrix R, wherein i is a first index indicating one of a plurality of rows of the autocorrelation matrix R, and wherein j is a second index indicating one of the plurality of columns of the autocorrelation matrix R,

wherein the codebook vector determiner (120) is configured to determine the codebook vector by applying the formula

$$f(\hat{e}) = \frac{(d^T \hat{e})^2}{\hat{e}^T R \hat{e}}$$

wherein R is the autocorrelation matrix, and wherein $\hat{e}$ is one of the codebook vectors of the speech coding algorithm, wherein $f(\hat{e})$ is a normalized correlation, and wherein d^T is defined according to

$$\frac{(e^T R \hat{e})^2}{(\hat{e}^T R \hat{e})} = \frac{(d^T e)^2}{(\hat{e}^T R \hat{e})},$$

wherein e is an original, unquantized residual signal.

2. An apparatus according to claim 1,

wherein the codebook vector determiner (120) is configured to determine that codebook vector $\hat{e}$ of the speech coding algorithm which maximizes the normalized correlation

$$f(\hat{e}) = \frac{(d^T \hat{e})^2}{\hat{e}^T R \hat{e}} \quad .$$

3. An apparatus according to claim 1 or 2,

wherein the matrix determiner (110) is configured to determine the vector coefficients of the vector r by applying the formula:

$$r(k) = h(k) * h(-k) = \sum_l h(l)h(l-k)$$

wherein h(k) indicates a perceptually weighted impulse response of a linear predictive model, and wherein k is an index being an integer, and wherein l is an index being an integer.

4. An apparatus according to one of the preceding claims,

wherein the matrix determiner (110) is configured to determine the autocorrelation matrix R depending on a perceptually weighted linear predictor.

5. An apparatus according to one of the preceding claims, wherein the codebook vector determiner (120) is configured to decompose the autocorrelation matrix R by conducting a matrix decomposition.

6. An apparatus according to claim 5, wherein the codebook vector determiner (120) is configured to conduct the matrix decomposition to determine a diagonal matrix D for determining the codebook vector.

7. An apparatus according to claim 6,

wherein the codebook vector determiner (120) is configured to determine the codebook vector by employing

$$\frac{(f^H D \hat{f})^2}{\hat{f}^H D \hat{f}},$$

wherein D is the diagonal matrix, wherein f is a first vector, and wherein $\hat{f}$ is a second vector.

8. An apparatus according to claim 6 or 7, wherein the codebook vector determiner (120) is configured to conduct a Vandermonde factorization on the autocorrelation matrix R to decompose the autocorrelation matrix R to conduct the matrix decomposition to determine the diagonal matrix D for determining the codebook vector.

9. An apparatus according to one of claims 6 to 8, wherein the codebook vector determiner (120) is configured to employ the equation

$$\| Cx \|^2 = \| DVx \|^2$$

to determine the codebook vector, wherein C indicates a convolution matrix, wherein V indicates a Fourier transform, and wherein x indicates the speech signal.

10. An apparatus according to one of claims 6 to 9, wherein the codebook vector determiner (120) is configured to conduct a singular value decomposition on the autocorrelation matrix R to decompose the autocorrelation matrix R to conduct the matrix decomposition to determine the diagonal matrix D for determining the codebook vector.

11. An apparatus according to one of claims 6 to 9, wherein the codebook vector determiner (120) is configured to conduct a Cholesky decomposition on the autocorrelation matrix R to decompose the autocorrelation matrix R to conduct the matrix decomposition to determine the diagonal matrix D for determining the codebook vector.

12. An apparatus according to one of the preceding claims, wherein the codebook vector determiner (120) is configured to determine the codebook vector depending on a zero impulse response of the speech signal.

13. An apparatus according to one of the preceding claims,

wherein the apparatus is an encoder for encoding the speech signal by employing algebraic code excited linear prediction speech coding, and

wherein the codebook vector determiner (120) is configured to determine the codebook vector based on the autocorrelation matrix R as a codebook vector of an algebraic codebook.

14. An apparatus for encoding a speech signal by determining a codebook vector of a speech coding algorithm, wherein the apparatus comprises:

a matrix determiner (110) for determining an autocorrelation matrix R, and

a codebook vector determiner (120) for determining the codebook vector depending on the autocorrelation matrix R,

wherein the matrix determiner (110) is configured to determine the autocorrelation matrix R by determining vector coefficients of a vector r, wherein the autocorrelation matrix R comprises a plurality of rows and a plurality of columns, wherein the vector r indicates one of the columns or one of the rows of the autocorrelation matrix R, wherein

$$R(i, j) = r(|i-j|),$$

wherein $R(i, j)$ indicates the coefficients of the autocorrelation matrix R, wherein i is a first index indicating one of a plurality of rows of the autocorrelation matrix R, and wherein j is a second index indicating one of the plurality of columns of the autocorrelation matrix R,

wherein the codebook vector determiner (120) is configured to decompose the autocorrelation matrix R by conducting a matrix decomposition,

wherein the codebook vector determiner (120) is configured to conduct the matrix decomposition to determine a diagonal matrix D for determining the codebook vector, and

wherein the codebook vector determiner (120) is configured to determine the codebook vector by employing

$$\frac{(f^H D \hat{f})^2}{\hat{f}^H D \hat{f}},$$

wherein D is the diagonal matrix, wherein f is a first vector, and wherein $\hat{f}$ is a second vector.

15. An apparatus for encoding a speech signal by determining a codebook vector of a speech coding algorithm, wherein the apparatus comprises:

a matrix determiner (110) for determining an autocorrelation matrix R, and

a codebook vector determiner (120) for determining the codebook vector depending on the autocorrelation matrix R,

wherein the matrix determiner (110) is configured to determine the autocorrelation matrix R by determining vector coefficients of a vector r, wherein the autocorrelation matrix R comprises a plurality of rows and a plurality of columns, wherein the vector r indicates one of the columns or one of the rows of the autocorrelation matrix R, wherein

$R(i, j) = r(|i-j|)$,

wherein $R(i, j)$ indicates the coefficients of the autocorrelation matrix R, wherein i is a first index indicating one of a plurality of rows of the autocorrelation matrix R, and wherein j is a second index indicating one of the plurality of columns of the autocorrelation matrix R,

wherein the codebook vector determiner (120) is configured to decompose the autocorrelation matrix R by conducting a matrix decomposition,

wherein the codebook vector determiner (120) is configured to conduct the matrix decomposition to determine a diagonal matrix D for determining the codebook vector, and

wherein the codebook vector determiner (120) is configured to conduct a Vandermonde factorization on the autocorrelation matrix R to decompose the autocorrelation matrix R to conduct the matrix decomposition to determine the diagonal matrix D for determining the codebook vector.

16. A system, comprising:

an apparatus (210) according to one of claims 1 to 15 for encoding an input speech signal to obtain an encoded speech signal, and

a decoder (220) for decoding the encoded speech signal to obtain a decoded speech signal,

wherein the decoder (220) is configured to receive the encoded speech signal, wherein the encoded speech signal comprises an indication of a codebook vector, being determined by the apparatus according to one of claims 1 to 15,

wherein the decoder (220) is configured to decode the encoded speech signal to obtain the decoded speech signal depending on the codebook vector.

17. A method for encoding a speech signal by determining a codebook vector of a speech coding algorithm, wherein the method comprises:

determining an autocorrelation matrix R, and

determining the codebook vector depending on the autocorrelation matrix R,

wherein determining an autocorrelation matrix R comprises determining vector coefficients of a vector r, wherein the autocorrelation matrix R comprises a plurality of rows and a plurality of columns, wherein the vector r indicates one of the columns or one of the rows of the autocorrelation matrix R, wherein

$R(i, j) = r(|i-j|)$,

wherein $R(i, j)$ indicates the coefficients of the autocorrelation matrix R, wherein i is a first index indicating one of a plurality of rows of the autocorrelation matrix R, and wherein j is a second index indicating one of the plurality of columns of the autocorrelation matrix R,

wherein determining the codebook vector is conducted by applying the formula

$$f(\hat{e}) = \frac{(d^T \hat{e})^2}{\hat{e}^T R \hat{e}}$$

wherein R is the autocorrelation matrix, and wherein $\hat{e}$ is one of the codebook vectors of the speech coding algorithm, wherein $f(\hat{e})$ is a normalized correlation, and wherein d^T is defined according to

$$\frac{(e^T R \hat{e})^2}{(\hat{e}^T R \hat{e})} = \frac{(d^T e)^2}{(\hat{e}^T R \hat{e})},$$

wherein e is an original, unquantized residual signal.

18. A method for encoding a speech signal by determining a codebook vector of a speech coding algorithm, wherein the method comprises:

determining an autocorrelation matrix R, and

determining the codebook vector depending on the autocorrelation matrix R,

wherein determining an autocorrelation matrix R comprises determining vector coefficients of a vector r, wherein the autocorrelation matrix R comprises a plurality of rows and a plurality of columns, wherein the vector r indicates one of the columns or one of the rows of the autocorrelation matrix R, wherein

$R(i, j) = r(|i-j|)$,

wherein $R(i, j)$ indicates the coefficients of the autocorrelation matrix R, wherein i is a first index indicating one of a plurality of rows of the autocorrelation matrix R, and wherein j is a second index indicating one of the plurality of columns of the autocorrelation matrix R,

wherein decomposing the autocorrelation matrix R is conducted by conducting a matrix decomposition,

wherein conducting the matrix decomposition is conducted to determine a diagonal matrix D for determining the codebook vector, and

wherein determining the codebook vector is conducted by employing

$$\frac{(f^H D \hat{f})^2}{\hat{f}^H D \hat{f}},$$

wherein D is the diagonal matrix, wherein f is a first vector, and wherein $\hat{f}$ is a second vector.

19. A method for encoding a speech signal by determining a codebook vector of a speech coding algorithm, wherein the method comprises:

determining an autocorrelation matrix R, and

determining the codebook vector depending on the autocorrelation matrix R,

wherein determining an autocorrelation matrix R comprises determining vector coefficients of a vector r, wherein the autocorrelation matrix R comprises a plurality of rows and a plurality of columns, wherein the vector r indicates one of the columns or one of the rows of the autocorrelation matrix R, wherein

$R(i, j) = r(|i-j|)$,

wherein $R(i, j)$ indicates the coefficients of the autocorrelation matrix R, wherein i is a first index indicating one of a plurality of rows of the autocorrelation matrix R, and wherein j is a second index indicating one of the plurality of columns of the autocorrelation matrix R,

wherein decomposing the autocorrelation matrix R is conducted by conducting a matrix decomposition,

wherein conducting the matrix decomposition is conducted to determine a diagonal matrix D for determining the codebook vector, and

wherein conducting the matrix decomposition to determine the diagonal matrix D for determining the codebook vector is conducted by conducting a Vandermonde factorization on the autocorrelation matrix R to decompose the autocorrelation matrix R.

20. A method comprising:

encoding an input speech signal according to the method of one of claims 17 to 19 to obtain an encoded speech signal, wherein the encoded speech signal comprises an indication of a codebook vector, and

decoding the encoded speech signal to obtain the decoded speech signal depending on the codebook vector.

21. A computer program for implementing the method of one of claims 17 to 20, when being executed on a computer or signal processor.

Claims

1. An apparatus for encoding a speech signal by determining a codebook vector of a speech coding algorithm, wherein the apparatus comprises:

a matrix determiner for determining an autocorrelation matrix R, and

a codebook vector determiner for determining the codebook vector depending on the autocorrelation matrix R,

wherein the matrix determiner is configured to determine the autocorrelation matrix R by determining vector coefficients of a vector r, wherein the autocorrelation matrix R comprises a plurality of rows and a plurality of columns, wherein the vector r indicates one of the columns or one of the rows of the autocorrelation matrix R, wherein

$$R(i\ ,\ j)\ =\ r(|i-\ j|),$$

wherein $R(i, j)$ indicates the coefficients of the autocorrelation matrix R, wherein i is a first index indicating one of a plurality of rows of the autocorrelation matrix R, and wherein j is a second index indicating one of the plurality of columns of the autocorrelation matrix R.

2. An apparatus according to claim 1,

wherein the matrix determiner is configured to determine the vector coefficients of the vector r by applying the formula:

$$r(k) = h(k) * h(-k) = \sum_{l} h(l)h(l-k)$$

wherein h(k) indicates a perceptually weighted impulse response of a linear predictive model, and wherein k is an index being an integer, and wherein l is an index being an integer.

3. An apparatus according to claim 1 or 2,

wherein the matrix determiner is configured to determine the autocorrelation matrix R depending on a perceptually weighted linear predictor.

4. An apparatus according to one of the preceding claims,

wherein the codebook vector determiner is configured to determine the codebook vector by applying the formula

$$f(\hat{e}) = \frac{(d^T \hat{e})^2}{\hat{e}^T R \hat{e}}$$

wherein R is the autocorrelation matrix, and wherein $\hat{e}$ is one of the codebook vectors of the speech coding algorithm, and wherein is a normalized $f(\hat{e})$ correlation.

5. An apparatus according to claim 4,

wherein the codebook vector determiner is configured to determine that codebook vector $\hat{e}$ of the speech coding algorithm which maximizes the normalized correlation

$$f(\hat{e}) = \frac{(d^T \hat{e})^2}{\hat{e}^T R \hat{e}} \quad .$$

6. An apparatus according to one of the preceding claims, wherein the codebook vector determiner is configured to decompose the autocorrelation matrix R by conducting a matrix decomposition.

7. An apparatus according to claim 6, wherein the codebook vector determiner is configured to conduct the matrix decomposition to determine a diagonal matrix D for determining the codebook vector.

8. An apparatus according to claim 7,

wherein the codebook vector determiner is configured to determine the codebook vector by employing

$$\frac{(f^H D \hat{f})^2}{\hat{f}^H D \hat{f}} \quad .$$

wherein D is the diagonal matrix, wherein f is a first vector, and wherein $\hat{f}$ is a second vector.

9. An apparatus according to claim 7 or 8, wherein the codebook vector determiner is configured to conduct a Vandermonde factorization on the autocorrelation matrix R to decompose the autocorrelation matrix R to conduct the matrix decomposition to determine the diagonal matrix D for determining the codebook vector.

10. An apparatus according to one of claims 7 to 9, wherein the codebook vector determiner is configured to employ the equation

$$\| Cx \|^2 = \| DVx \|^2$$

to determine the codebook vector, wherein C indicates a convolution matrix, wherein V indicates a Fourier transform, and wherein x indicates the speech signal.

11. An apparatus according to one of claims 7 to 10, wherein the codebook vector determiner is configured to conduct a singular value decomposition on the autocorrelation matrix R to decompose the autocorrelation matrix R to conduct the matrix decomposition to determine the diagonal matrix D for determining the codebook vector.

12. An apparatus according to one of claims 7 to 10, wherein the codebook vector determiner is configured to conduct a Cholesky decomposition on the autocorrelation matrix R to decompose the autocorrelation matrix R to conduct the matrix decomposition to determine the diagonal matrix D for determining the codebook vector.

13. An apparatus according to one of the preceding claims, wherein the codebook vector determiner is configured to determine the codebook vector depending on a zero impulse response of the speech signal.

14. An apparatus according to one of the preceding claims,

wherein the apparatus is an encoder for encoding the speech signal by employing algebraic code excited linear prediction speech coding, and

wherein the codebook vector determiner is configured to determine the codebook vector based on the autocorrelation matrix R as a codebook vector of an algebraic codebook.

15. A method for encoding a speech signal by determining a codebook vector of a speech coding algorithm, wherein the method comprises:

determining an autocorrelation matrix R, and

determining the codebook vector depending on the autocorrelation matrix R,

wherein determining an autocorrelation matrix R comprises determining vector coefficients of a vector r, wherein the autocorrelation matrix R comprises a plurality of rows and a plurality of columns, wherein the vector r indicates one of the columns or one of the rows of the autocorrelation matrix R, wherein

$$R(i, j) = r(|i-j|),$$

wherein $R(i, j)$ indicates the coefficients of the autocorrelation matrix R, wherein i is a first index indicating one of a plurality of rows of the autocorrelation matrix R, and wherein j is a second index indicating one of the plurality of columns of the autocorrelation matrix R.

16. A decoder for decoding an encoded speech signal being encoded by an apparatus according to claim 1 to obtain a decoded speech signal.

17. A method for decoding an encoded speech signal being encoded according to the method of claim 15 to obtain a decoded speech signal.

18. A system, comprising:

an apparatus according to one of claims 1 to 14 for encoding an input speech signal to obtain an encoded speech signal, and

a decoder according to claim 16 for decoding the encoded speech signal to obtain a decoded speech signal.

19. A method comprising:

encoding an input speech signal according to the method of claim 15 to obtain an encoded speech signal, and

decoding the encoded speech signal according to the method of claim 17 to obtain a decoded speech signal.

20. A computer program for implementing the method of claim 15, 17 or 19, when being executed on a computer or signal processor.