

Claims

1. Method for estimating the shape of an acoustic trailing antenna (12), wherein the shape is estimated using Kalman filtering,
5 ~~characterized in that~~ the deterministic part ($u(k_i)$) of the equation of state of the Kalman filter is set to zero, consecutive discrete points in time (k_i) are predefined and an estimated shape of the trailing antenna (12) is described at each of the predefined points in time (k_i), by a model-based state vector ($x(k_i)$), characterized in that ~~wherein~~ the model-based state
10 vectors ($x(k_i)$) are determined by the estimated time behavior of a mechanical model (24) of the trailing antenna (12) and by movements of a pull point (16) of the trailing antenna (12) assumed to be known, the deviation of the current model-based state vector ($x(k_i)$) for one or more previous model-based state vectors ($x(k_{i-1})$) is determined and is
15 considered to be a current matrix ($\tilde{F}(k_i)$) and the current transition matrix ($F(k_i)$) for the Kalman filtering is regularly updated using the matrices determined ($\tilde{F}(k_i)$).
2. Method in accordance with Claim 1,
20 characterized in that
the trailing antenna (12) is assumed to be divided into multiple segments (22) and Kalman-based state vectors ($\hat{x}(k_i)$) are regularly updated using Kalman filtering, wherein each Kalman-based state vector ($\hat{x}(k_i)$), each estimated using Kalman filtering, has values describing current locations,
25 orientations and/or shapes of several or all of the segments (22).
3. Method in accordance with Claim 1 or 2,
characterized in that
in the Kalman filtering, a current Kalman-based state vector ($\hat{x}(k_i)$) is
30 determined using a prediction step (34) and a correction step (36) following the prediction step (34), wherein a current uncorrected Kalman-based state vector ($\hat{\tilde{x}}_a(k_i)$) is determined in the prediction step (34) by multiplying one

or more Kalman-based state vectors determined beforehand ($\hat{x}(k_{i-1})$) and is converted into the current Kalman-based state vector ($\hat{x}(k_i)$) using the transition matrix ($F(k_i)$) and the current uncorrected Kalman-based state vector ($\hat{x}_{\bar{a}}(k_i)$) in the correction step (36).

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4. Method in accordance with Claim 3, characterized in that

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one or more of the segments (22) each have one or more sensors for the determination of measurement readings ($\mathcal{Y}$) for the variables, location, orientation and/or shape of the respective segments (22), wherein the measurements ($\mathcal{Y}$) of the same variables at the same point in time (k_i) are depicted in a measurement vector ($z(k_i)$), and are determined in the correction step (36) of the current Kalman-based state vector ($\hat{x}(k_i)$) by determining the difference between the measurement vector ($z(k_i)$) and the current uncorrected Kalman-based state vector ($\hat{x}_{\bar{a}}(k_i)$), weighted by multiplication by the current Kalman matrix ($F(k_i)$), and the product is converted into the current Kalman-based state vector ($\hat{x}(k_i)$) by addition of the current uncorrected Kalman-based state vector ($\hat{x}_{\bar{a}}(k_i)$).

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- 20 5. Method in accordance with one of the preceding Claims, characterized in that

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the current Kalman matrix ($\hat{K}(k_i)$) is determined using the covariance matrix of the estimation error ($\hat{P}_{\bar{a}}(k_i)$) of the current uncorrected Kalman-based state vector ($\hat{x}_{\bar{a}}(k_i)$), wherein the covariance matrix ($\hat{P}_{\bar{a}}(k_i)$) of the estimation error of the current uncorrected Kalman-based state vector ($\hat{x}_{\bar{a}}(k_i)$) is determined using the current transition matrix ($F(k_i)$) and the covariance matrix ($\hat{P}(k_{i-1})$) of the estimation error of the previously determined Kalman-based state vector ($\hat{x}(k_{i-1})$).

6. Method in accordance with Claim 5, characterized in that

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interferences with the sensors and the error-prone measurement readings (ϑ) of the sensors caused by this are assumed, a covariance matrix (R) of these errors of measurement in the measurement readings (ϑ) of the sensors is determined once at the beginning of the estimation or at predefined intervals and this covariance matrix (R) is used to determine the Kalman matrix ($\hat{K}(k_i)$).

7. Method in accordance with Claim 6,
characterized in that
the measurements of the sensors are filtered.
8. Method in accordance with one of the Claims 5 to 7,
characterized in that
a covariance matrix (Q) of an assumed additive process noise is determined once at the beginning of the estimation of the shape or at predefined intervals and is used to determine the covariance matrix ($\hat{P}_{\hat{a}}(k_i)$) of the estimation error of the respective current uncorrected Kalman-based state vector ($\hat{x}_{\hat{a}}(k_i)$).
9. Method in accordance with one of the preceding Claims,
characterized in that
a first Kalman-based state vector ($\hat{x}(k_0)$) for determining subsequent Kalman-based state vectors ($\hat{x}(k_i)$) and a first model-based state vector ($x(k_0)$) for determining subsequent model-based state vectors ($x(k_i)$) by reference to an assumed shape of the trailing antenna (12) are determined at the beginning of the estimation.
10. Method in accordance with one of the preceding Claims,
characterized in that
the mechanical model (24) of the trailing antenna (12) incorporates a mass-spring system, on which one or more points, e.g. centers of mass or any of one or more other points, respectively for each Segment (22) of the trailing

antenna (12) are considered as a mass (m) and adjoining masses (m) are considered to be connected to one another by springs (28) and the estimated time behavior of the mechanical model (24) of the trailing antenna (12) is determined by the accelerations of the masses (m), wherein the accelerations are described by the tractive forces (30a, 30b) of the springs (28) and by external effects of forces on the mass-spring system, in particular, by assumed hydrodynamic forces, assumed counterforces caused by displaced fluid and assumed static buoyancy.

10 11. Method in accordance with one of the preceding Claims, characterized in that cyclic values of the model-based state vectors ($x(k_i)$), such as estimated compass readings of the segments (22), are converted into equivalent linear values or measurements (ϑ) prior to determining the current transition matrix ($F(k_i)$) and cyclic measurements (ϑ) of the measurement vectors ($z(k_i)$) are converted into equivalent linear values or measurements (ϑ) prior to determining the deviation between the respective measurement vector ($z(k_i)$) and the current uncorrected Kalman-based state vector ($\hat{x}_{\hat{a}}(k_i)$).

20 12. Method in accordance with one of the preceding Claims, characterized in that the time interval (Δt) between the defined points in time (k_i) is less than the time interval between the points in time, in which the location of the pull point (16) is determined, and current locations of the pull point (16), which, in terms of time, are between the determined points in time, are determined by interpolation.

30 13. Method in accordance with one of the preceding Claims, characterized in that Kalman-based state vectors ($\hat{x}(k_i)$) are determined with a lower repetition rate than model-based state vectors ($x(k_i)$).

14. Method in accordance with one of the preceding Claims,
characterized in that
the model-based state vectors ($x(k_i)$) and the Kalman-based state vectors
5 ($\hat{x}(k_i)$) only exhibit discrete values of estimated locations, orientations
and/or shapes or values derived from these values.
15. Device for estimating the shape of an acoustic trailing antenna (12),
wherein the device is designed in such a way as to estimate the shape
10 using a means for Kalman filtering,
~~characterized in that~~ the device is also designed in such a way as to set the
deterministic part ($u(k_i)$) of the equation of state of the Kalman-Filter to
zero, to predefine successive discrete points in time (k_i) and to describe
an estimated shape of the trailing antenna (12) at each of the predefined
15 points in time (k_i) by a model-based state vector ($x(k_i)$), characterized in
that ~~wherein~~ the device is designed in such a way as to determine the
model-based state vectors ($x(k_i)$) by the estimated time behavior of a
mechanical model (24) of the trailing antenna (12) and by the movements
of a pull point (16) of the trailing antenna (12) assumed to be known, to
20 determine the deviation of the current model-based state vector ($x(k_i)$) for
one or more previous model-based state vectors ($x(k_i)$), to consider each
of these deviations to be a current matrix ($\tilde{F}(k_i)$) and to update the current
transition matrix ($F(k_i)$) of the Kalman filter regularly using the matrices
($\tilde{F}(k_i)$) determined.