REGELUNGSMETHODEN UND ROBOTIK

Titel der Ausarbeitung

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***Zusammenfassung*— Hierhin kommt eine kurze (5-6 Sätze) Zusammenfassung der Arbeit. In diesem Fall beschreibt das Dokument die LaTeX-Vorlage für die Erstellung der Ausarbeitungen eines Projektseminars.**

***Abstract*— This is the english translation of your „Zusammenfassung “.**

I. Sound source localization

The sound source localization algorithm was implemented based on the MUSIC (MUltiple SIgnal Classification) algorithm. Figure 1 displays the structure of the sound source localization algorithm [1]. The localization algorithm performs first by acquiring the multi-channel sound signals from the microphones and getting the multi-channel spectrum by means of the Fourier transformation. Then the cross-spectrum correlation matrix is computed to make the eigenvalue decomposition of the averaged correlation matrix over a time interval. The next stage employs the steering/position vectors and the eigenvectors of the noise subspace to calculate the MUSIC responses of each frequency bin. The final stages include the averaging of the MUSIC responses over a frequency range and identifying the direction of arrival (DOA) of the sound sources by means of peak picking. The following subsections go into the details of the MUSIC algorithm and remaining stages.

A. MUSIC algorithm

The Multiple Signal Classification algorithm can be defined as the determination of different parameters of multiple wavefronts that enter an array of antennas or sensors [2].
The MUSIC algorithm provides asymptotically unbiased estimates of different parameters such as number of signals, direction of arrival (DOA), polarization, strength and cross correlation among the directional waveforms, and many others. The M array elements receive the waveforms from the sources that are linear combinations of the D incidents wavefronts[1] and noise. This can be expressed as in equation 1.

$$\begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_M \end{bmatrix} = \begin{bmatrix} \mathbf{a}(\theta_1) & \mathbf{a}(\theta_2) & \dots & \mathbf{a}(\theta_D) \end{bmatrix} \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_D \end{bmatrix} + \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_M \end{bmatrix} \tag{1}$$

$$\text{or } \mathbf{X} = \mathbf{AF} + \mathbf{W} \tag{2}$$

where the vector $\mathbf{X}$ represents the M received waveforms, the incident signals are represented by the vector $\mathbf{F}$ in phase and amplitude at some reference point, and the complex noise is represented by the vector $\mathbf{W}$.
The elements a_{ij} from the matrix $\mathbf{A}$ are functions of the angle of arrival and the position of the array elements. Therefore, each element a_{ij} depends on the position relative to the origin of the ith array element and the response of the incident signal from the direction jth. The jth column of matrix $\mathbf{A}$ is known as the mode vector of responses to the direction of arrival θ_j of the jth signal. That is, the mode vector $\mathbf{a}_j$ is equivalently to the direction of arrival θ_j.

It can be deducted from equation 1 that the vector $\mathbf{X}$ is a linear combination of the mode vectors $\mathbf{a}(\theta_j)$ in which the elements of the matrix $\mathbf{F}$ are the coefficients of this combination. The directions of arrival of multiple incident wavefronts are calculated by determining the intersections of the $\mathbf{a}(\theta)$ continuum with the range space of $\mathbf{A}$.

For determining the source localization, the correlation matrix of the input signals needs to be calculated. That is,

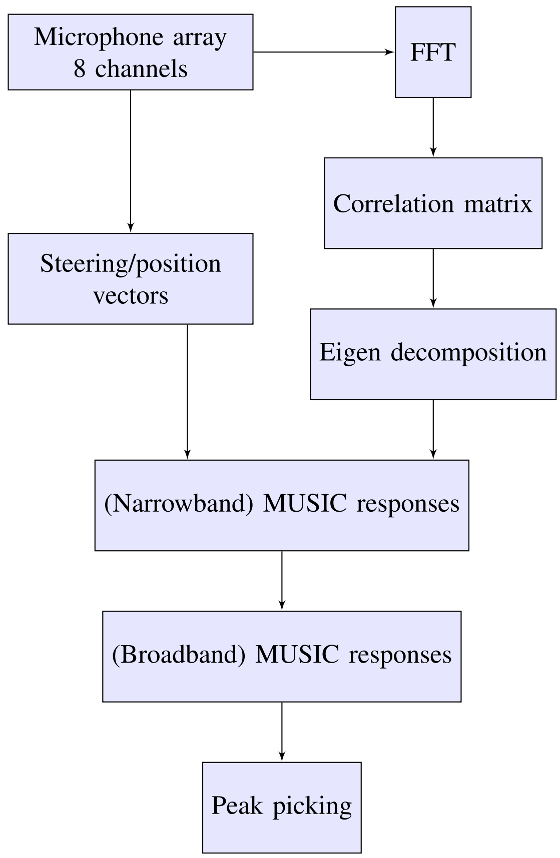

Bild 1. Block diagram of the sound source localization

Diese Arbeit wurde von Akad.Titel Vorname Name unterstützt.

[1]explicar que es wavefront

the covariance matrix of the $\mathbf{X}$ vector is

$$\mathbf{S} = \mathbf{X}\mathbf{X}^* = \mathbf{A}\mathbf{F}\mathbf{F}^*\mathbf{A}^* + \mathbf{W}\mathbf{W}^*. \tag{3}$$

Where the * operator indicates the conjugate transpose operator. With the covariance matrix of the microphone array observations is performed a principal component analysis on this matrix to separate the disjoint signal and noise subspaces. For these means, the eigenvalue decomposition or singular decomposition of the covariance matrix $\mathbf{S}$ is carried out. The M-th space correlation matrix obtained in 3 is decomposed in the signal and noise subspaces as per

$$\mathbf{S} = \mathbf{Q}\mathbf{\Lambda}\mathbf{Q}^{-1} \tag{4}$$

in which $\mathbf{Q}$ is a $M \times M$ matrix with the eigenvectors $\mathbf{q}_i$ of $\mathbf{S}$ written in the column i-th, and the matrix $\mathbf{\Lambda}$ is a diagonal matrix containing the eigenvalues.
The singular vectors $\mathbf{q}_i$ are orthogonal to the space spanned by the columns of $\mathbf{A}$ or in other words the vectors contained in the columns of $\mathbf{A}$ are perpendicular to each other. Since the eigenvectors $\mathbf{q}_i$ have correlation to the power of the incident wavefronts, the eigen vectors can be divided into N noise eigenvectors and D incident signal mode vectors, in which the D vectors correspond to the eigenvalues with greatest value. For instance, the matrix $\mathbf{Q}$ can be written as

$$\mathbf{Q} = [\mathbf{q}_1, \mathbf{q}_2, \ldots, \mathbf{q}_M]$$

and the split matrix gives the mode vectors $[\mathbf{q}_1, \mathbf{q}_2, \ldots, \mathbf{q}_D]$ and the noise eigenvectors $[\mathbf{q}_1, \ldots, \mathbf{q}_N]$.

The next step is to solve for the incident mode vectors. In order to do that the spectrum for SSL is calculated using the noise eigenvectors as per

$$P = \frac{\mid \mathbf{H}^*\mathbf{H} \mid}{\sum\limits_{i=1}^{N} \mid \mathbf{H}^*\mathbf{q}_i \mid}. \tag{5}$$

Where $\mathbf{H}$ is the transfer function of the sound propagation. The transfer function can be determined numerically or by measurements. The transfer function is a multichannel expression that depends on the sound S_i in direction θ_i in view of the microphone array to the i-th microphone and is expressed as

$$\mathbf{H} = [H_1, \ldots, H_M]. \tag{6}$$

The transfer function is to be determined with anteriority and is also called as the steering vector.

The numerator of equation 5 represents the multiplication between the steering vector (transfer function) and the noise-related eigenvector. This product is theoretically zero if the transfer function is a vector corresponding to the desired sound; making the quotient of the spectrum diverge infinitely. In reality, the denominator does not go exactly to zero due to the effects of noise but an abrupt peak can be observed.
Equation 5 represents the spectrum for every frequency a broadband SSL is performed for the desired frequencies as

$$\hat{P} = \sum_{\omega=\omega_{min}}^{\omega_{max}} W_\Lambda W_\omega P. \tag{7}$$

ω_{min} and ω_{max} determine the desired frequency bands, W_Λ is the eigenvalue weight and is the square root of the maximum eigenvalue. Finally, W_{omega} is the spectrum weight factor.

The search of the sound is performed in the frequency bands aforementioned for $\hat{P}$ where the maxima are identified by local maximum searching or the hill-climbing method

Anhang I
Optionaler Titel

Anhang eins.

Anhang II

Anhang zwei.

Anhang III
Richtlinien für das Verfassen wissenschaftlicher Arbeiten

Im Folgenden werden einige wichtige Richtlinien zusammengefasst. Die Aufzählung ist allerdings nicht erschöpfend.

- Klare Darstellung, was der Eigenanteil ist und was schon vorhanden war.
- Vorsicht vor Plagiaten: vollständige Quellenangaben, auch bei Bildern. Es sollte immer klar ersichtlich sein, was der Eigenanteil ist und was aus Quellen entnommen wurde.
- Bilder nicht 1:1 aus Quellen kopieren.
- Diskussion der Ergebnisse (Simulationen, Messungen, Rechnungen): Wurde das Ergebnis so erwartet? Wenn nein, was sind mögliche Gründe?
- Autoren: Als Autor sollte jede Person in Betracht gezogen werden, die wesentlich zur Arbeit beigetragen hat (siehe auch die Empfehlungen der DFG diesbezüglich, vgl. [4]). Alle Personen mit kleinerem Beitrag (fachliche Hinweise, Beteiligung an Datensammlung etc.) können in der Danksagung oder einer Fußnote erwähnt werden.
- Formeln in den Satz einbetten und alle Variablen bei der ersten Verwendung im Text einführen. Beispiel: Für die Temperatur ergibt sich damit

  $$T(h) = Kh^2,$$

  sie hängt quadratisch von der Höhe h ab.

Anhang IV
Hinweise zur Notation

- Abkürzungen bei der ersten Verwendung erklären, z.B.: "DFG (Deutsche Forschungsgemeinschaft)".
- Formelzeichen konsistent benennen, nicht zwischen den Abschnitten umbenennen. Formelzeichen kursiv schreiben, z.B. Variable a.
- Auf korrekte Dimensionen und Einheiten achten. Für Einheiten das SI-System verwenden, z.B. das LaTeX-Paket *units* oder *SIunits*.
- Zahlen: Im Deutschen Komma als Dezimaltrennzeichen, im Englischen Punkt.

- Tabellen haben Überschriften, Diagramme haben Unterschriften.
- Diagramme: Achsenbeschriftungen hinreichend groß (insbesondere die Zahlen).
- Diagrammunterschriften sollen im Wesentlichen ausreichen, um das Diagramm zu verstehen.
- Indizes werden *kursiv* gesetzt, wenn sie die Bedeutung von Variablen haben, ansonsten **normal**. Beispiele: $V_k,\ k = 1, 2, \ldots$ und V_{input}.

DANKSAGUNG

Wenn ihr jemanden danken wollt, der Euch bei der Arbeit besonders unterstützt hat (Korrekturlesen, fachliche Hinweise,...), dann ist hier der dafür vorgesehene Platz.

LITERATURVERZEICHNIS

[1] Ishi, C.T. et al., *Evaluation of a MUSIC-based real-time sound localization of multiple sound sources in real noisy environments.*, Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Conference on. 2009. 2027-2032. ©2009 Institute of Electrical and Electronics Engineers.

[2] R. Schmidt, *Multiple emitter location and signal parameter estimation,* in IEEE Transactions on Antennas and Propagation, vol. 34, no. 3, pp. 276-280, Mar 1986. doi: 10.1109/TAP.1986.1143830

[3] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.

[4] Deutsche Forschungsgemeinschaft, *Vorschläge zur Sicherung guter wissenschaftlicher Praxis*, Denkschrift, Weinheim: Wiley-VCH, 1998.

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