Direction Finding for Wideband Signals using Nonuniform Linear Arrays

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Introduction

The focus of the study is to investigate Direction-of-Arrival (DOA) for wideband signals using using Nonuniform Linear Arrays (NLAs). The effect of array geometry on the DOA estimation performance will be considered. The aim is to determine whether the performance of an NLA can be improved by changing the positions of the innermost sensors in an array. Effect of the number of sources on the array geometry will also be investigated.

In Literature a number of techniques for DOA estimation using NLA are provided. The methods include; array interpolation, manifold seperation, Fourier-domain Root-MUSIC, Fourier-domain line-search MUSIC and Fourier-domain weighted least-squares [1]. However, these techniques work well for narrow-band sources. In this study, a technique using array interpolation is used to perform DOA for wideband signals [2]. Array interpolation generates a set of *virtual arrays* with same array manifold for each frequency band. The technique is used where multiple wideband sources are received by an arbitrary array. In this study the arrays NLAs. The virtual arrays used are linear and uniformly spaced and then the Root MUSIC is applied.

The performance analysis of DOA estimation for wideband signal using NLAs will be performed using appropriate performance measures. Potential performance measures that can be used include the stochastic Cramer-Rao bound [3], and the asymptotic root mean square error (RMSE) of MUSIC [4]. Furthermore, the performance measures for Root-MUSIC with an interpolated uniform linear array is performed[5]. Computer simulations will be performed to verify the results.

The research problem

The main aim of NLA DOA is the efficient use of array sensors so as to obtain DOA performance comparable to a ULA with the same aperture. One of the advantages of NLAs over ULAs is that they cover the same aperture with fewer sensors, thereby maximising the efficient use of sensors. However, for a ULA with the same number of sensors as an NLA, the ULA performs better. Therefore, when designing NLAs the aim is to obtain an array with performance comparable to that of a ULA with the same aperture. The main research problem is to find the most favourable array geometries for DOA estimation for wideband signals using NLAs.

Objectives of work

The objectives of the proposed research are given below:

- Evaluation and analysis of the array interpolation technique for DOA estimation for wideband signals.
- Evaluation and analysis of the effect of array geometry on DOA estimation performance.

Array interpolation

Array interpolation is an array processing technique that allows NLA DOA estimation problems to be reduced to ULA problems. Array interpolation approximates the steering of the real sensor as

$$\mathbf{a}(\theta) \approx \mathbf{G}_1\, \mathbf{b}_1(\theta),$$

where $\mathbf{b}_1$ is the steering vector of a virtual ULA, and $\mathbf{G}_1$ is the interpolation matrix that minimizes the interpolation error. With the virtual ULA steering matrix determined, conventional root-MUSIC can then be applied to estimate DOA.

Array Models

NLA sensor array geometries are normally designed such that the distance between adjacent sensors is an integer multiple of a unit distance **d**<**λ/2**, where, **λ** is the wavelength. For NLAs where the inter-element spacing is greater than half the wavelength DOA, ambiguities may result. However, this is not always the case as arrays without ambiguities can be constructed with a minimum spacing much greater than **λ/2**. In cases where the inter-element spacing is larger the **λ/2**, two different DOA sources may result in the same covariance matrix, thereby rendering the NLA unable to distinguish between different signal sources. This ambiguity problem is resolved by having atleast one set of adjacent sensors with an inter-element spacing less than **λ/2**. In the proposed thesis the array structure is characterized using a metric called the co-array matrix. Figure 1 shows a Partly Filled Nonuniform Linear Array (PFNLA), where one section of the array is a ULA and another is an NLA. Other types of geometries to be investigated include, non-redundant NLAs, minimun redundant NLA.

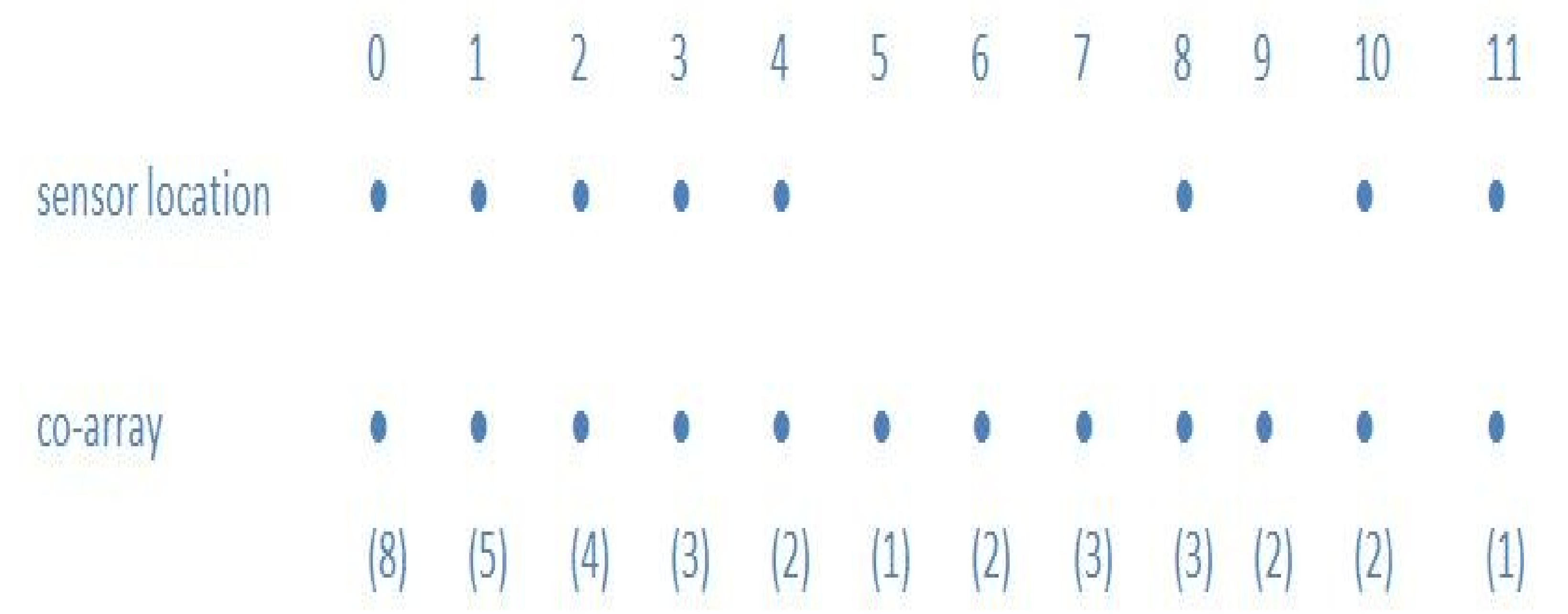

Figure 1. Example array geometry where the array geometry is a combination of uniform linear array and a nonuniform linear array. This is the Partly Filled Nonuniform Linear Array (PFNLA)

Conclusion

Array interpolation was proposed as the technique for performing DOA for wideband signals using NLAs. The virtual arrays were chosen to be linear and equally spaced so that the root-MUSIC algorithm could be used on the resultant ULA virtual array. It is expected that some NLA geometries will give better asymptotic performance than conventional root-MUSIC applied to the real ULA with the same aperture length. Indeed the geometry of the NLA is the main factor affecting performance and accuracy of DOA estimation. The main issue regarding this investigation is that wideband signals, instead of narrowband signals are to be estimated thereby increasing the computational complexity.

References

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