華仁青年講座

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Signal Processing for Large Arrays: Convolutional Beamspace, Hybrid Processing, and Distributed Algorithms

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Abstract: Direction-of-arrival (DOA) estimation of incoming waves for a passive antenna array is an important topic in array signal processing. Meanwhile, its 2-D extension, millimeter-wave (mmWave) MIMO channel estimation, is a key problem in 5G/6G communications. To compensate for the strong mmWave path loss, large arrays are used to get large beamforming gain. The main contribution addressed in this talk is to propose low-complexity DOA and channel estimation methods especially effective for large arrays. To achieve low complexity, three main aspects are explored: beamspace methods, hybrid analog and digital processing, and distributed algorithms. The first two are focused on in this talk. Convolutional beamspace (CBS) is proposed for DOA estimation based on passive arrays. In CBS, the array output is spatially filtered, followed by uniform decimation (downsampling) to achieve dimensionality reduction. CBS enjoys lower computational complexity, increased parallelism of subband processing, and improved DOA resolution. Moreover, unlike classical beamspace, it allows standard DOA estimation methods like root-MUSIC and ESPRIT to be used for uniform linear arrays without additional preparation since CBS preserves the Vandermonde structure. Then, hybrid CBS is proposed, where an analog combiner is used to reduce the number of RF chains and thus hardware complexity. The analog combiner is designed as a phase shifter network with unit-modulus entries. It is shown that any general CBS filter can be implemented despite the unit-modulus constraints. Moreover, a new scheme of CBS is proposed based on nonuniform decimation and difference coarray method. This allows us to identify more sources than RF chains. Nonuniform CBS can also achieve better estimation performance than uniform CBS given the same number of RF chains. The 2-D case of mmWave MIMO channel estimation is also briefly mentioned. The better performance of the proposed methods than previous methods are shown by simulations.

Bio: Po-Chih Chen received the B.S. and M.S. degrees in electrical engineering and communication engineering from National Taiwan University, in 2015 and 2017, respectively. He received the Ph.D. degree in electrical engineering at the California Institute of Technology (Caltech), USA, in 2024. He has been an assistant professor (H&J Youth Chair Professor, 華仁青年講座教授) at the Institute of Communications Engineering, National Yang Ming Chiao Tung University since August 2024. His research interests are in array signal processing, signal processing for communications, digital signal processing. Recent research topics include direction-of-arrival (DOA) estimation, mmWave MIMO communications, hybrid analog/digital processing, and distributed algorithms.