Circulant-type Experimental Design and its Application to fMRI Experiments

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Abstract

Cost-efficient experimental designs have been widely used nowadays. Orthogonal arrays are commonly used to study the effects of many factors simultaneously, but they do not exist in any sizes. Recently, orthogonal arrays with circulant property receive great attention and are applied to experiments in many fields, such as functional magnetic resonance imaging (fMRI), which is a pioneering technology for studying brain activity in response to mental stimuli. Efficient fMRI experimental designs are important for rendering precise statistical inference on brain functions, but a systematic construction method for this important class of designs does not exist. In this work, we propose an innovative and unified construction method for efficient, if not optimal, fMRI designs via circulant almost orthogonal arrays (CAOAs). Since circulant Hadamard matrices, that can also be viewed as circulant orthogonal arrays of symbols two and strength two, have been conjectured nonexistence, CAOAs are considered.

We characterize this new class of efficient designs and propose a systematic construction via a newly invented algebraic tool called complete difference system (CDS). We not only prove the equivalence relation of CDS and CAOA, but also construct many classes of CAOAs with very high efficiency. Finally, we apply these efficient CAOAs to fMRI experiments, showing that our constructed designs have better properties than the traditional designs in terms of cost-efficiency and effect independency. This is a joint work with Dr. Frederick Kin Hing Phoa of Academia Sinica, Taiwan and Dr. Ming-Hung Kao of Arizona State University-Tempe, USA.