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Book Review

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The *Design of Experiments Server* (DES) at *www.iasri.res.in/design* is an evolving website offering a wide range of tools and materials in support of all who are involved in designing experiments, from the scientist in the field to the consulting statistician and, to a lesser degree, the mathematical researcher. Hosted by the Indian Agricultural Statistics Research Institute in New Delhi, it is a project spearheaded by Drs. Rajender Parsad and V.K. Gupta and funded by The Indian Council of Agricultural Research.

The stated objective of DES is "to spread the advances in theoretical, computational, and statistical aspects of Design of Experiments...." Set against a background of rapidly evolving knowledge and pressure for ever more rapid communication, theirs is a timely effort aimed at augmenting the transition of design methodology from journal article to statistical practice. This review offers a snapshot of where DES currently stands, evaluations of the relative merits of its many facets, and suggestions for future development.

First it should be noted what the site is not. There is a seemingly boundless world of design techniques that no one site could reasonably encompass, and the parameters here are clearly drawn. DES does not offer design advice for experiments in which the variables the experimenter will manipulate may take values over continuous intervals (see later in this review for the one current exception). Thus it is not a resource for those wishing to navigate the vast design literature encompassing linear and nonlinear regression models, generalized linear models, spline models, additive models, differential equations models, nor even design techniques for response surface explorations. DES takes as its primary domain the many problems of *treatment design for continuous response*: the experimenter has a fixed set of structured or unstructured treatment conditions to compare for their effect on a continuous response variable, and must design so to account for sources of variability in the experimental material. DES addresses that domain with design catalogs, randomization routines, software details for popular statistical packages, and an online textbook whose chapters detail use and analyses for the most commonly employed classes of designs.

The Electronic Book is presented in two parts: Book I is *Design and Analysis of Agricultural Experiments* and Book II is *Advances in Data Analytical Techniques*. Book I provides background material on many traditional design classes, including BIBDs, PBIBDs, resolvable block designs, row-column designs, factorial designs, block designs with nested factors, and so on. There are some stylistic differences in writing here and throughout the site, owing to contributions from a number of authors. There is a chapter (or "module") on computer usage that includes the basics for, and information on analyzing data from designed experiments with SAS, Excel, and SPSS. Also included is documentation for the specialized software products SPBD (Statistical Package for Block Designs), SPAR (Statistical Package for Agricultural Research Data Analysis), and SPFE (Statistical Package for Factorial Experiments). SPBD, SPAR, and SPFE are available at a nominal cost from *http://iasri.res.in/iasriwebsite/software.htm*, as is the SPAD package mentioned below.

Book II also provides software information, some of it overlapping with Book I, but also including overviews for SYSTAT, Minitab, and Excel.

Documentation for two other specialized products, SPAD (Statistical Package for Augmented Designs), and ASReml (fits linear mixed models using residual maximum likelihood, *http://www.vsni.co.uk/software/asreml*), is found here. Standard design classes are again covered. However Book II's strength is in its coverage of numerous statistical techniques, far too many to list here. While Book I concentrates on design issues, Book II aims at being a general statistical reference for agricultural scientists.

There is nothing really new in Books I and II, nor is that their intent. What the Electronic Book accomplishes is bringing together a wealth of information for designing and analyzing experiments, with a particular focus on agricultural research. With so much information so readily available, the gap between the scientist in the field and the statistician in the academy has been effectively narrowed to the click of a mouse. And that same mouse can be used to post a problem to the DES discussion board, or send a direct e-mail query to the site, when direct assistance is required.

Specific examples and instructions for analyzing data from designed experiments, in addition to that found in the Electronic Book, is reached via the separate Analysis of Data tab. These examples are chiefly focused on implementation via SAS and SPSS.

Complementing these resources for understanding and analyzing designs are the very useful design generation and randomization facilities. Under the site's Online Design Generation I tab one can create and randomize unblocked designs (CRDs), complete block designs (RCBDs), Latin square designs, augmented designs, alpha designs, and (unrandomized) lattice designs. The CRDs and RCBDs can additionally be generated with a user-specified factorial structure on the treatments, if desired. These are the most commonly used designs in agriculture, making online randomizers especially welcome. However, it should be noted that the Latin square randomizer produces cyclic Latin squares that are randomized only with respect to symbols, not to rows or columns. The standard randomization procedure is to randomize all of treatment symbols, rows, and columns.

Incomplete block designs, also of use in agriculture, can be obtained via Block Designs > Generate Design Layout. Here designs for given numbers of treatments, blocks, and block size are retrieved from a database created by a design search algorithm. Randomization of these designs is not provided.

Currently two classes of designs of a more specialized nature are available via Online Design Generation II. Here one can obtain Hadamard matrices, important as fractional factorial designs for 2-level factors, of order up to 1000. Complete sets of mutually orthogonal Latin squares (MOLS), of order up to 1000 a prime or prime power, can also be generated, as either Latin squares or, equivalently, as orthogonal arrays. Two other classes of designs, supersaturated designs and block designs with factorial structure, are provided under Designs for Factorial Experimentation. None of these are produced in randomized form. One specialized class of designs for experiments with continuous predictors, namely mixture designs, can be generated under the Experiments with Mixtures tab, where background information for this class of experiments is also provided.

As evidence by pages that are currently under construction (for example, online designs for treatment versus control experiments, and for bioassays), DES is continuing to grow and improve. With kind tolerance of the developers, I will close this review by suggesting a few lines of what I believe would be fruitful modifications and additions.

A search tool would be of considerable help in site navigation. As pointed out earlier, there is partially overlapping material amongst the various pages, and a search engine would help one quickly identify all of the relevant pages for a targeted concept. Interested by the augmented design generator, it took me numerous tries to determine where augmented designs were discussed in the Electronic Book. A search could have led directly there (as could have a link on the augmented design generation page).

Producing randomized designs is an important aid to scientists. DES has provided an excellent service in generating some of the commonly used designs in randomized format, and could beneficially extend this to others mentioned above such as incomplete block designs, lattice designs, and block designs with factorial structure.

The design generators print their output to the user's screen. The user can then copy and paste into his or her own application. This is simple enough with small designs, but becomes unwieldy as design size grows (try it with a 1000×1000 Hadamard matrix). There can also be formatting difficulties when copying designs in this way. Preferable would be to offer the option of a download file.

The developers are especially encouraged to push towards expanding the scope of available online designs, by both expansion of current catalogs and introduction of new catalogs. As an example of the former, at least two mutually orthogonal Latin squares are known for all orders greater than six, and often more than two are known for non-prime/prime power orders. These could be fruitfully included in the MOLS catalog. Likewise, the online orthogonal array generator could be augmented with a great number of very useful designs, most notably both pure and mixed arrays with up to four levels. In the direction of new catalogs, resolvable designs are of special utility in agricultural experimentation, and the last decade has seen significant progress in development of good resolvable designs that reach beyond what is covered by lattice and alpha designs. DES would better serve its core audience by making these available online.

DES has many contributors other than Drs. Parsad and Gupta, and though too numerous to list here, all are to be congratulated for helping to make this a useful and accessible resource for agricultural scientists. The site has other facilities than those listed in this review, and you are encouraged to browse its pages to more fully understand its offerings. We all look forward to what the future will bring with this excellent design resource.

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