Statlab: An Interactive Teaching Tool for DOE

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Summary. An interactive web based teaching tool, Statlab, for Design of Experiments is presented. In this tool, the student is introduced to practical strategies for experimenting through virtual case studies. Statlab forces students to think about practical details since it hides options that students do not ask for. Engineering students as well as industrial participants in our courses consider Statlab as a stimulating learning environment. Statlab can be freely used through the web site www.win.tue.nl/statlab/.

1 Introduction

A good working knowledge of DOE (Design of Experiments) is essential for both industrial statisticians and engineers. It is therefore essential that statistics courses pay sufficient attention to this topic. However, a distinctive feature of DOE is that it is pro-active, unlike many other statistical techniques that are focused on extracting useful information after data has been collected. Hence, this requires a teaching approach that forces students to actively think about several aspects of setting up an experimental design, without steering the student too much. An additional feature required by us is that there should be room for the student to make mistakes and learning from them. In order to create such a teaching environment to be used in statistics courses at various departments of the Eindhoven University of Technology, a web based tool called Statlab has been developed. This tool adapts itself to the student, who is being led through one of several possible case studies. In this paper we describe the teaching philosophy behind this tool, as well as its technical implementation. The tool has been receiving positive reactions from students, who generally consider using Statlab as a stimulating teaching environment.

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2 Philosophy of Teaching DOE

Experimental design is a pro-active activity, unlike many other statistical methods. We feel that teaching experimental design should include conferring feeling for required choices in designing experiments. This should include learning from the consequences of omissions. Standard statistical packages are not suitable for these teaching tools, because they present many options to the student, who either accepts the default settings or simply chooses options that the software offers. We require a teaching environment that forces students to actively think about the construction of an experimental design, as well as analyzing data collected from such a design. In order to stay close to practice, the students should go through the following phases (see [4] for lots of useful advice and [1] for an example of an implementation in a physical experiment):

- Gather information about the goal of the experiments.
- Gather information about the experimental facilities.
- Construct an appropriate design.
- Analyse data collected from the chosen design.
- Formulate conclusions and recommendations.

Since statistical software often has an interface to a catalogue of experimental designs, we require that students are able to intelligently choose a design rather than have to construct designs themselves like fractions of factorial designs. We thus have the following requirements for our teaching environment:

- Ability to adapt to student behaviour.
- Ability to answer questions about the experiment.
- Hide options unless asked for.
- Force students to make choices.
- Create designs.
- Ability to simulate data from chosen design (including steepest ascent optimization, see Fig. 1).
- Ability to analyse simulated data (including determination of stationary points of response surfaces).

We implicitly assume that students have been introduced to the basics of DOE by lectures or self-study. The environment should help students to transfer their theoretical knowledge to practical situations, as well as develop a feeling for practical issues. These requirements, as well as our wish to teach large groups (over 100 students) led us to the choice of developing a dedicated software program for performing virtual experiments. The same conclusion has been reached by others (see e.g., [2] and [3]). We refer to [5] for a discussion on advantages and disadvantages of virtual experimentation environments, including a list of common pitfalls. In order to be flexible, the current version of Statlab is web based, but can also be run as a stand-alone application (see Sect. 3 for technical details).

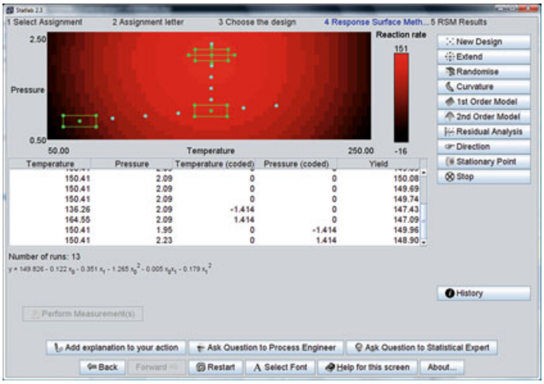

Fig. 1. A screenshot of a response optimization assignment

Statlab currently contains 15 case studies with an indication of its difficulty. The difficulty of a case study depends on a number of issues listed below (between parentheses we list the corresponding statistical notions):

- Restrictions on number of runs (fractions, replications).
- Restrictions on number of experiments under similar circumstances (blocks).
- Restrictions on experimental region (factor level settings, step size).
- Irregularities in the collected data (outliers).
- Knowledge of interactions.
- Curvature of response surface (centre points, lack-of-fit tests).
- Stationary points of the response surface that are not optima (saddle-point).

Of course, there are also issues like randomization that are always part of the case study. Each case study begins with an assignment letter that describes the problem in general engineering terms. We took this idea from the DOE case study in the German on-line statistics tool EMIL@A-stat (`www.emilea.de`). Students have to determine what kind of design is appropriate for this assignment. We currently offer the choice between screening designs, response surface designs and robust (Taguchi) designs.

Questions about the assignment may be asked to the process engineer through key words (see Fig. 2). The tool has a long list of synonyms. The process engineers knows how many experiments may be executed, sometimes has knowledge about interactions, knows whether experiments may be carried out under similar circumstances etc. She has no background in statistics, so she cannot (and is also not willing to) answer questions about randomization or centre points. A statistical expert is available if students wish to get a brief explanation about statistical concepts (again through key words entered by students). In order to teach students that time is limited in industry,

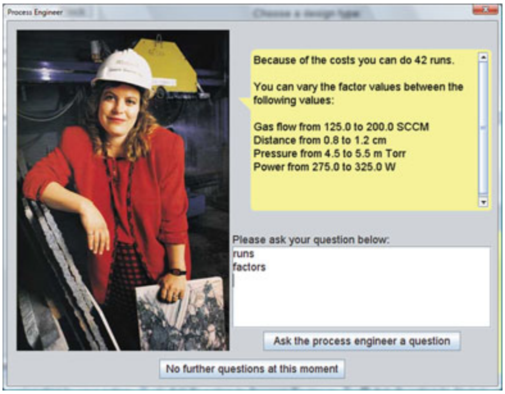

Fig. 2. The student should ask questions about the assignment to the process engineer

the process engineer display increasing levels of irritation when the student keep asking questions. The standard list of possible designs does not contain blocked designs or fractional designs. Students do not get a larger list of designs, unless they enter appropriate key words in the *Design options* field. The current version of Statlab has the following additional features:

- Adds a trend if the student forgets to randomize.
- Adds outliers to simulated data.
- Has a Design Wizard that creates and visualizes blocked fractional factorial designs (including the alias structure).
- Gives students feedback on their work by mentioning possible mistakes.
- Allows students to add explanation to their choices when needed.
- Implements an automatic grading system of student work that provides relevant feedback to the student.

Outliers should be noted by students and reported to the process engineer, who will ask the lab to investigate the suspicious observations. Currently the students get the answer that the observation was indeed wrong and obtain a corrected measurement. The feedback to students only gives possible mistakes, in order to avoid students to push some extra buttons without understanding their omissions. The Design Wizard is also separately available through `www.win.tue.nl/statlab/designApplet.html` and may support lectures on construction of fractional factorial designs.

3 Technical Implementation

Statlab is a freely accessible Java program. It is freely available through the URL `www.win.tue.nl/statlab`. The minimum required Java version is 1.4. The latest Java version can be downloaded freely from `java.com`. In order to use Statlab during official examinations, the Java security settings must allow Statlab to save the results to the user's hard disk, and send an email to the teacher. When Statlab is started for the first time, the user is prompted to grant these permissions. But even when the Java security settings are correct, firewalls or virus scanners might prohibit Statlab to send email messages. This is why the opening page of Statlab contains a "Detect Java Security" button that checks whether the right Java version is installed and whether Statlab is allowed to save results to disk and send an email. Students should always run this security check on the system that they will use during the exams. By using Java Webstart, the tool can also be used off-line. When the tool is used on-line, automatic updates of the software will be installed without bothering the user. In this way we circumvented managing updates with users of our tool.

Currently, our tool supports two languages (Dutch and English), but the software architecture has been set up in such a way that we can support more languages. The tool automatically detects browser and language settings of the user.

4 Experiences

Throughout the years we have using our tool in various courses. These courses were mainly for Bachelor and Master's students of the Mathematics, Chemical Engineering, Industrial Engineering and Mechanical Engineering Departments, but we also used Statlab in industrial DOE courses. We used our tool both for instruction during lectures, as for official examinations. Using our tool during lectures usually gave rise to lively discussions about experimental design. Initially, students find it difficult to ask simple questions about designs. It is often an eye-opener that in practice the number of experiments that can be executed is restricted. A class demonstration together with the on-line student manual has proved to be sufficient for students to get acquainted with Statlab. Part of the case studies can be accesses freely so that students can practice. Case studies that we use for official examinations are password protected. We specifically ask questions about student experiences with Statlab in the standard course evaluation forms. Most students indicate that they feel that Statlab made statistics more attractive to them because it made them experience the practical sides of statistics. Furthermore, they indicated that using Statlab enhanced their understanding of applying DOE in practice. A minority adapts a minimalist approach by trying to work through the case studies using pre-defined lists of design options and questions to the process engineer.

Since at our university all students possess a personal notebook, it is the responsibility of the students to ensure that Statlab runs well on their notebooks. Over the years we had several hundreds of students using Statlab during official exams, but we only had very few cases where Statlab did not work during an official examination. For such emergency cases, we always have one or two spare notebooks available. In order to prevent students from communicating via internet with each other during examinations, an ICT expert in our department developed a tool that prevents any communication between notebooks until the assignment has been submitted officially through the internet. Grading of examinations is easy since Statlab generates an easy-to-use, extensive grading report for each student where errors and omissions are marked in red. Instructors have the ability to overrule the grading results of Statlab.

5 Future Developments

Statlab is in continuous development. Although the number of case studies is large compared to other tools that we are aware of, we would like to have more case studies so that users with different backgrounds can choose case studies with context that appeal to them. We welcome feedback and ideas for new case studies from other instructors. There is a teacher manual that will be sent on request to persons that identify themselves are being involved in teaching. We plan to add more complexity in the initial and reporting phases of the assignment, to add functionality in communication with the virtual process engineer in order to imitate real-life situations more closely. Finally, we would like to add other types of designs like mixture designs and optimal designs.

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