Mat-2.4177 Seminar on Case Studies in Operational Research

Designing Layouts for Specimens in Agricultural Experiments Suffering from External Distractions

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Introduction

Kemira GrowHow is one of the leading fertilizer and fodder phosphate manufacturers in Europe. It operates in close connection with farmers, breeders, grocery- and fodder producers, chemistry industry and distributors. Kemira GrowHow pursues to develop partnerships that benefit all the parties involved. In its operations Kemira GrowHow is concentrated in creating advanced and tailored products for crop cultivation, animal feed industry and other industries.

Kemira GrowHow has 13 production facilities in eight countries as well as its own phosphate mine. The company's products are sold in more than 100 countries and its net sales in 2006 were EUR 1,166 billion. Kemira GrowHow employs around 2,100 people worldwide and it is listed on the Helsinki Stock Exchange. In 2007 Yara International ASA, the largest fertilizer producer in the world acquired Kemira GrowHow. The acquisition started when State of Finland sold its share in Kemira GrowHow.

Background

One important research method for Kemira GrowHow is to conduct field experiments. These experiments are made to find out the effects, different kind of factors and their levels have on plant breeding. These experiments are conducted indoor as well as outdoor. Examples of different factors and their levels could be: whether the crop has ailment prevention or not and the level of fertilizer used. Conducting these field experiments may involve some kind of distractions that make the interpretation of the results more difficult or even impossible. The distractions could be for example unequal sunlight for the plants, temperature alternations in the experiment or even wildlife. The problem these distractions make is that if a part of the experiment is ruined and it contains most of the specimens with a certain level of a factor, the analysis of the effect of this factor could become impossible.

Our task is to develop an algorithm or criteria with what better layouts for these field experiments can be made. Better layout here means that if something distracts the experiment, the layout is made so that the analysis of the experiment can be conducted in best possible way. The assumption here is that the possible areas that may encounter distraction can be evaluated. Our experiment planning algorithm should take the following aspects in consideration: number and the levels of factors in the experiment, the shape of the experiment area, the shapes and locations of the possible distractions and other restrictions due to the arrangements of the experiment. We will also create an indicator that shows how well our layout fits for a certain situation with specific threats, factors and factor levels. We also intend to study if the following operations could enhance the results of the experiments: Changing the shape of the experiment area, increasing the amount of specimens with certain factor levels, or shaping the form of possible distraction areas. It would also be useful if we could determine when the problems that distractions cause can be avoided and when not, given certain experiment parameters.

There is another project group studying how to enhance the analysis of field experiments. This study is concentrated on how statistically adjust to the fact that these field experiments are 2-dimensional. If our group notices that we benefit from collaborating with the other group, we intend to do so.

Research objectives

Our research objectives have been formulated based on discussions with the representative of our client company as well as with our professor. Our main research objective can be stated as follows:

This study aims to provide the theory and tools for designing more robust layouts for specimens in agricultural experiments.

In order to accomplish this main objective, we can define the following sub-objectives for our study.

1. **Literature survey.** In order to better understand the restrictions and finer points of agricultural experiment design, we will conduct a review of the relevant literature.

2. **Identification of risks.** We will attempt to identify the different kinds of risk factors that can affect the quality of agricultural experiments for our client company.

3. **Mathematical model.** We will describe the problem our client company is facing in mathematical terms by creating a model for the layout of their experiments.

4. **MATLAB-program.** We aim to create a piece of software for MATLAB which will enable the user to automatically generate good layouts for specimens depending on variables the user enters.

5. **Quality.** We will define a measure for the quality of the layout of any given experiment. This will enable us to show the benefit of our solution compared to the current practise in our client company.

Research strategy

Literature review

Our literature review will consist of any articles deemed relevant to our investigation as well any highly regarded textbooks on agricultural experiment design. The articles will be sought through the University’s academic search portals with relevant keywords. We are especially interested in prior studies of the subject, which will provide us with valuable insights and enable us to avoid earlier mistakes.

Identification of risks.

We will identify the possible risks for the experiment through discussions with the client company as well as by reviewing past data and scientific articles. We will then compile a list of them and attempt to estimate the probabilities and damages associated with each risk.

Mathematical model

Our mathematical model will be identified by working alternately as a team and in pairs. We will first identify possible seeds for the model in a brainstorming session. Thereafter we will continue to work on the most promising ideas in smaller groups, thus developing alternate possibilities for our model. Once each idea has been developed enough for its feasibility to be assessed, we will evaluate the models again as a group. The most feasible and effective model will be identified, or we will possibly combine several models to find a satisfactory one. This will then become the model we will offer in our final solution. Our definition for the quality of the solution will most likely go hand in hand with our model development with several alternatives being distilled into one.

MATLAB

This will almost certainly be the most challenging part of our study, as our team has relatively little experience with the use of the MATLAB-programming language, or with any mathematical computer software for that matter. However, working as a team we will in turn generate and evaluate each other’s code, thus helping each other identify errors and solve problems in the code. After identifying our mathematical model we will identify various ways how the model could be translated into a MATLAB-program. Obvious concerns in this phase are usability, versatility, reliability and computing power.

Resources

The project team consists of five undergraduate students from Department of Industrial Management and Engineering and Department of Engineering Physics and Mathematics. The team has chosen Ville-Veikko Venojärvi as its project leader. Our main external stakeholders are Professor of Systems and Operations Research Ahti Salo and Jukka Sinisalo, who is our contact person at Kemira GrowHow. Ville's responsibilities as a project leader include communication with these stakeholders.

After the project plan is finished and accepted, the team will divide into groups of two and three so that one group can start to do the literature survey on the subject and the other can focus on mathematical modelling and MATLAB-programming. Risk analysis and formulating the quality indicator are to be done by the whole team.

Project schedule

The planned schedule presented in Table 1 acts a guideline in our work. Its task is to help us to see how the progress of planned tasks and activities. There can be some overlapping between the different parts, like literature survey and mathematical modelling but mostly the previous tasks have to be completed before later tasks can be began. There are also some deadlines in the project schedule that marked red in Table 1.

Table 1

	Week	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Planning	**Intial meetings with stakeholders**	■	■											
	Defining the problem		■	■										
	Initial Research			■	■									
	Making the project plan			■	■									
Research	**Literature survey**					■	■	■						
	Risk analysis						■	■	■					
	Modelling the problem					■	■	■						
Problem solving	**Programming MATLAB**						■	■	■	■				
	Testing the program									■	■			
	Formulating quality indicator										■	■		

Reporting	Project plan reporting Mid-term reporting Final reporting

Risks

The major concern in this study is the quality of the layouts suggested by the method we are about to develope. It is easy to determine just some kind of rule for the layout but finding the optimal or even a ”good enough for getting reliable results” -layout can prove to be difficult. Here we have considered few of the risks more closely.

Defining the ”goodness” of the layout

One of the most important steps in the study is to define how we can measure the ”goodness” of a layout. We have to be able to define this indicator in such way that it really tells us how good the layout is and enables us to compare different layouts with each other. There is a risk that we won’t be able to add all the relevant factors in the indicator and then the optimal layout would be biased. We plan to use some kind of weighted utility function where we could take multiple factors into account simultaniously and discuss the weights with the client in order to minimize this risk.

Usability and Matlab

One risk is that we will be able to describe the method for creating the optimal layouts in words but we fail to express it correctly as a mathematical algorithm. Kemira GrowHow explicitly demanded for a MATLAB algorithm as a practical tool for creating the layouts. Another risk here is that the MATLAB algorithm will work in theory but is incapable of taking in all the constraints of the real life and thus won’t work in practise. Since our team is not very experienced with MATLAB programming these risks have to be taken seriously. However, we have acknowledged this problem and we plan to devote much of our time in writing the algorithm. In addition, our contact from Kemira GrowHow promised to help us with MATLAB-related issues.

Identifying the external distractions and modeling them

The way we can identify and model the external distractions will have an effect on the quality of our layouts. These distractions may come in many forms and they migth be difficult to predict. Modeling them must be based on real-life material and the algorithm should be flexible towards new user-defined distractions. The risk is that the method will work only on few theoretical cases without strong links to real-life situations.