Computer-aided statistical modelling fights pollution

Henrik Madsen, Poul Thyregod, Florin Popentiu, and Grigore Albeanu help control pollution from a cement plant with non-linear regression

www.enbis.org

Modern societies are, almost literally, built with cement, but the cement industry consumes energy and natural resources while producing potentially hazardous emissions. It is difficult to control both the cement production process and the pollution level.

A computer-aided modelling and pollution control tool called PoLogCem (Pollution Logistic Cement), based on the data flow given in figure 1, was designed to:

(a) Develop mathematical models of environmental pollution;
(b) Monitor production and its influence on pollution; and
(c) Search for optimal solutions, with minimum pollution effects, for production planning.

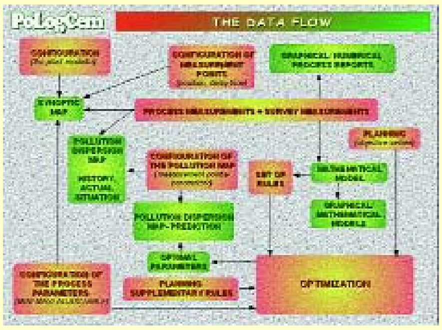

Figure 1. Data flow in the PoLogCem software

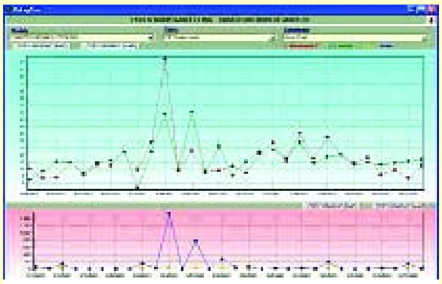

Figure 2. Scientific visualisation with the modelling module

The modelling module provides the specific functions to establish a mathematical model for the pollution. These functions are:

- Management of the pollution data;
- Model editing, including piecewise non-linear functions and their syntactical analysis;
- Non-linear parameter estimation; and
- Assessment of the adequacy of the designed models, by helping the end-user to determine experimentally the parameters of the environment pollution.

A snapshot of some graphical visualisation is presented in figure 2.

The logistic module provides reports for monitoring the pollution level and the contribution of each item of equipment to the pollution level.

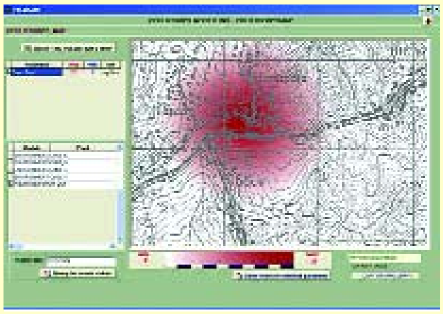

Figure 3. A map of environmental pollution at Tasca, Romania.

The optimisation module, based on the management principle of a large system, implements algorithms to minimise production costs while fulfilling the production plan under conditions of process restrictions. The pollution map can be visualised in the end of both the modelling and optimisation process, as shown in figure 3.

The software is being tested for the Moldocim Cement Plant in Romania.

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LETTER FROM THE PRESIDENT

ENBIS now has a national representative in almost every country in Europe. I recently emailed them to ask for their support in promoting ENBIS to the top 10 companies in each country and had a very pleasing response. The next step for our executive committee is to obtain feedback from members to see how they feel about their membership. This will guide our promotion of ENBIS in places where there are no members. We need national representatives to encourage their colleagues to contribute articles for the ENBIS magazine in *SCW*.

One of the main strengths of ENBIS is the fascinating mix of different cultures, and case studies are a good way of showcasing these. *SCW* is delivered only to those members who have ticked the box in their personal information, so we need to encourage members to do this.

Our fifth conference will be in Newcastle on 14 to 16 September. The conference will have three parallel streams. One stream will focus on practical applications of statistics, a main emphasis of ENBIS. Another stream will focus on advances in applied statistics, an equally important part of ENBIS. We have so much to fit into the third stream that it will also be packed with novel approaches to problem-solving, using statistics in business and industry. We have workshops led by interest groups, and an unmissable one-day workshop on statistical consulting skills, led by Soren Bisgaard and Sue Ellen Bisgaard.

There is more information on the ENBIS website (www.enbis.org). Newcastle is a fabulous location for a conference and we look forward to welcoming you there in September.

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How to make the trains run on time

Elizabeth Viles and David Puente offer a new way of improving the corrective maintenance of an electronic communication and control system for trains

Most important railway companies in Europe have communication and control systems in their trains based on the Train Communication Network (TCN) standard. This allows the interchange of information, as well as the operation of the train, to be flexible and to make use of new developments such as GPS, GSM and Internet. The snag is that a failure in a critical element of the communication and control system can put the whole train out of service.

Railway companies ask for availability to be as close to 100 per cent as possible, imposing stiff penalties in cases of failure during the warranty period. As trains are sold worldwide, and because the maintenance team works for the manufacturer, suppliers must pay for any expenses during the warranty period, although they are not directly in charge of maintenance. The equipment must be robust and easy to maintain.

Maintenance of train-control systems has traditionally been reactive: once a breakdown was detected, it was repaired and, at best, the information kept for statistics or for later preventive action. While modern control systems have some auto-diagnosis and communication, preventive maintenance is limited to the replacement of electromechanical components.

Maintenance should increase the availability and reliability of systems and equipment, and decrease their repair time. We speak about optimising maintenance in terms of minimising both its costs and the resources required. Thus, any tool that allows the maintenance team to spend less time looking for a failure and its cause is an improvement.

We have designed a way of making corrective maintenance easier and more efficient, speeding up the detection of failures, locating each failure, finding its cause, repairing or replacing the affected components and putting the system or equipment back into operation. The tool we have devised will also gather information about the system throughout its useful life, allowing the constant evaluation of the system's reliability. We call the tool Functional Analysis for Maintenance (FAM).

FAM is widely applicable, especially where preventive maintenance is not feasible. The more complex the equipment or system, the more difficult it is to solve the problem. Hence, the potential benefits of FAM are greater for complex equipment or systems where the source of failure is more difficult to find.

The tool allows a manufacturer to consider new ways of managing maintenance, such as doing it remotely or subcontracting it. Such management of maintenance is appreciated when the product is sold abroad, because it makes the maintenance of the equipment or system more accessible and easier, even by non-qualified personnel.

FAM thoroughly studies and analyses the functionality of the equipment or system. Its strategy is to separate that into primary functions, secondary functions, tertiary functions, and so on. This division finishes when the most basic functions have been analysed. FAM involves two steps: the design of the functional network and the functional study.

Functional network

The functional network is a graphical representation used to define, organise and connect the different functions that the equipment or system and its modules and components must fulfil. The network has two element types: function and control.

Function is the action, task or goal that a device or a group of devices has in the system for which it was designed. The functional network or map represents each function by using a rectangle. Control is the task of devices that supervise the normal operation of one or several specific functions. It is not a function of the system but a check used to evaluate whether the system is functioning properly or not. A circle in the functional network represents each control.

Therefore, every function of every device in the equipment or system and the relationships between them must be identified and are represented graphically. Once the network is built, the complete set of functions of the system becomes available. If we read the network from left to right we can understand how the product works, whereas reading it in the opposite direction and tracing the different branches, will lead us to the different devices involved in a concrete functional failure. Figure 1 shows a generic functional network.

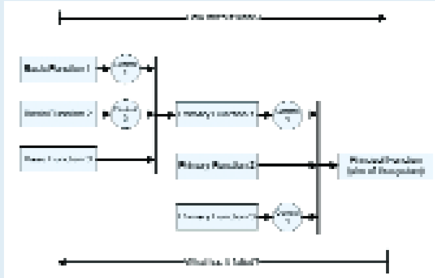

Figure 1. Generic functional network

Functional study

The functional study is the analysis of each specific function in the network and deals with the failures that could occur during its operation, their possible involvement in the failure of higher-level functions and the state or warnings of the controls in the case of a breakdown. With the functional study we gather the relevant information of each subsystem for a function. This enables us to identify which repairable device has caused the breakdown.

Maintainence is a key factor of the equipment or system in the railway sector for two reasons:

- A train can be off-line due to a failure. This causes service delays and hence passenger dissatisfaction; and
- The maintenance team works for the train manufacturer; it is in charge of the maintenance of all the devices and mechanisms that make up the train, even if they have not manufactured them.

We have applied FAM to a control and supervision system for trains, see Figure 2. This system is installed throughout the train and its fundamental functions are to:

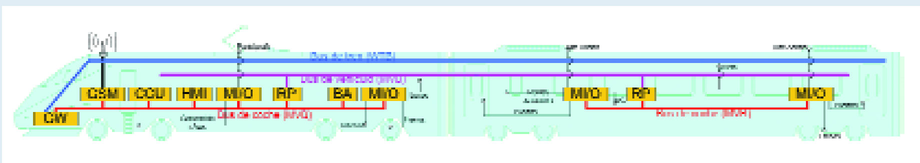

Figure 2. Electronic control and supervision system for a train unit

- Control the train;
- Monitor the state of the train and its electronic devices; and
- Manage the internal communications of the train.

The functional study identifies the functional failures and their effects on the network, and records the state of the controls for each case in an easy-to-understand way.

Our software helps the maintenance team to locate a failure. It is a web-based application with an easy-to-use interface for searching the functional network automatically through a series of questions. It then presents a list of the possible devices or mechanisms that could have caused the breakdown. It also gives specific instructions to re-establish its functionality if necessary. Figure 3 shows a generic example.

The program can also gather information about the operational history of the equipment

Figure 3. FAM Program

or system, such as the number of failures per device, the accumulated incurred cost per functional failure or the mean time of repair per functional failure.

The application of FAM for equipment or systems, while they are working, has many advantages. The most notable are:

- It makes it easy for the maintenance team to work and it gives them more autonomy;
- It increases the availability of the product, minimising the repair time while reducing the incurred cost of the corrective maintenance;
- It identifies improvement opportunities as it generates information about the most problematic failures of the equipment or system; and
- It is an easy-to-use qualitative tool.

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Statistical practitioners – a new profession in business and industry?

Ron Kenett, Maria Ramalhoto, and John Shade suggest that industrial statisticians could take a lesson from medical diagnosticians

Medical practitioners are experts in the diagnosis and treatment of illnesses and injuries. Medicine could provide a role model for practitioners of industrial statistics who are concerned with the diagnosis and treatment of problems in business and industrial processes.

Statisticians usually work with process-experts to diagnose problems and to generate and test ideas leading to process improvement. Some members of ENBIS have argued that the creation of a library reflecting the body of knowledge now in use would greatly aid the development of industrial statistics into a more widely recognised profession. Among other benefits, this should allow methodology leaders in business, such as master black belts in six sigma programmes, to obtain a comprehensive picture of what their statistical practitioners might tackle, and how. For example, profiles of a variety of industries could show the types of problems and product-development opportunities to which the statistical practitioner could contribute. Complex designs requiring optimisation may have inadequate measurement processes, poorly monitored and adjusted production processes. Mis-matched inventory levels and consumer-demand estimation are some commonplace opportunity areas that could be made more focused with the benefit of industry-specific insights.

Many problems recur across industries and even within companies and other organisations. At the same time, managers and others can be bewildered by the range of approaches that have been promoted. These include TQC, TQM, SPC, Lean, Zero Defects, Six Sigma, Poka Yoke, Quality Circles, DOE, TPM, Design for X where X can be any of reliability, manufacturability, cost reduction, robustness, maintainability, modularity. Individual contributors such as Juran, Deming, and Taguchi pass in and out of fashion – praised by some, derided by others. Out of all this, patterns of successful responses to problems can be identified and stored in the library to help new as well as experienced practitioners gain a balanced perspective of what might be done and how. See boxes for examples.

Imagine a resource, possibly a database of some kind, which would allow statistical consultants to obtain some suggestions as to what ideas, ➤

What is Six Sigma?

Six Sigma provides companies with a series of interventions and statistical tools that lead to breakthrough profitability and impressive gains in quality, whether a company's products are durable goods or services.

Sigma is a letter in the Greek alphabet used to denote the standard deviation of a process (standard deviation measures the variation or amount of spread about the process mean). A process with 'Six Sigma' capability means having 12 standard deviations between the upper and lower specification limits. Process variation is reduced so that no more than 3.4 parts per million fall outside the specification limits. The higher the sigma number, the better.

The 'Six Sigma' term also refers to a philosophy, goal and or methodology utilised to drive out waste and improve the quality, cost and time performance of any business. Black Belts with 100 per cent of their time allocated to projects can execute five or six projects during a 12-month period.

Six Sigma implementation is through projects. Projects can be of different size and duration. We define a project as a structured and systematic approach to achieving Six Sigma levels of improvement.

Six Sigma levels of quality are achieved using the Measure, Analyse, Improve, Control, Problem-Solving, and Improvement sequence. Crucial to any successful Six Sigma implementation are its Champions. These senior management personnel are charged with driving and supporting Six Sigma to achieve business and operational objectives by driving out waste and increasing customer satisfaction.

Six Sigma DMAIC

The DMAIC problem-solving roadmap widely used in Six Sigma programmes is an example of a 'pattern', a guide to what has been successful in the past in similar situations. In Six Sigma, the relevant situation is when there are people available to tackle relatively tough problems for which causes and solutions are not at all clear.

D for DEFINE. Establish why this problem matters to the business and what kind of impact can be made on it by a specified group in a specified time (usually three to nine months)

M for MEASURE. Clarify what is already known about the problem, and be sure to include an assessment of how trustworthy are the data and measurement processes used to assess the problem

A for ANALYSE. Investigate the likely causes of the problem and seek to narrow down the focus to one or more 'root causes'.

I for IMPROVE. Take the root cause, and find possible solutions. Choose the best one.

C for CONTROL. Ensure the solution is well-implemented and a monitoring system is in place to give early warning of the problem returning, or of the solution being mis-applied.

➤ practical tips or solutions might help in a given situation. Suppose, further, that this resource was created by statistical consultants to reflect what they saw as successful solutions that could be applied time and again to various recurring situations. These are patterns that we might use time after time, as these situations are met in different industries, in different assignments.

Why have some statistical methods been so successful in helping business and industry? Part of the answer may lie in the power of scientific method: the forming of ideas that can be tested before being accepted as reliable guides to future performance. This is a key element of six sigma programmes. Another part of the answer may lie in the addressing of human irrationalities. We may be less rational than many might suppose. We tend to jump to conclusions far too easily, hang on to demonstrably wrong ideas far too long, and be excessively influenced by our interpretation of our most recent data. On top of this, we are vulnerable to being dominated by strong personalities, dramatic events, and the pursuit of our own apparent self-interest in hierarchies and networks of power and influence. Statistical methods help us, in the midst of all these distractions, to clarify what we know, what is most important, when action is called for in response to data and when it is not, and which factors are most likely to be effective in changing our processes for the better.

Statistical consultants have procedures for planning the details of a consulting assignment, for reviewing data sets and detecting missing or suspicious values, for continuous improvement using the Deming-Shewhart PDSA cycle, for structuring an intervention in some process, and so on. Most consultants have a set of such techniques that they bring to bear almost automatically in the appropriate situation. For example, see the box on DMAIC for problem-solving. There are many such prescriptions for problem-solving and management, and statistical practitioners need rational ways to pick and choose amongst them. An early step is the 'botanical' task of collecting and classifying prescriptions in ways that will reveal their basic features and the situations in which they have been successful. The Statistical Consultancy Interest Group (SCIG) is promoting a discussion among practitioners on suggestions for items to be included in the proposed patterns repository. The SCIG is one of several interest groups in ENBIS and, like the others, is keen to recruit new members. The group will meet again at the Newcastle conference in September, 2005.

Total Quality Roadmaps

SITUATION: companywide improvement effort, with almost everybody involved in self-starting teams, mainly in existing workgroups. Here is the guidance used at Hewlett-Packard in 1986 to help everyone to get started:

1. Who are my customers?
2. What do they need?
3. What is my product or service?
4. What are my customers' expectations and measures?
5. Does my product or service meet their expectations?
6. What is the process for providing my product or service? and
7. What action is required to improve that process?

A specific project was asked to follow this roadmap:

1. Select an Issue;
2. Write an 'Issue Statement; (to state the intended result of process intervention);
3. Identify the process and draw a flowchart of it;
4. Select process performance measures;
5. Conduct a cause and effect analysis;
6. Collect and analyse data;
7. Identify major causes and plan improvements;
8. Take corrective actions;
9. Collect and analyse data; and
10. If objectives are met, then document and standardise; otherwise return to step 4 or to step7.

Robust design

Examples: Choose the dimensions and material composition of an engine component

Context: Make products that minimise losses associated with deviations from ideal or target values of performance characteristics.

Problems: Multiple sources of variation can knock a manufactured product off target, and some compromise over design may be desirable to produce products robust to uncontrolled sources of variation such as environmental conditions.

Solution: Identify control and noise factors, and conduct multi-factor experiments to identify impacts on location and spread of response variables, and in due course identify optimal product specifications and/or processes.

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FIFTH ENBIS CONFERENCE

This will be held in Newcastle from 14 to 16 September. More information is available via the ENBIS website (www.enbis.org).