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# Industrial mathematics

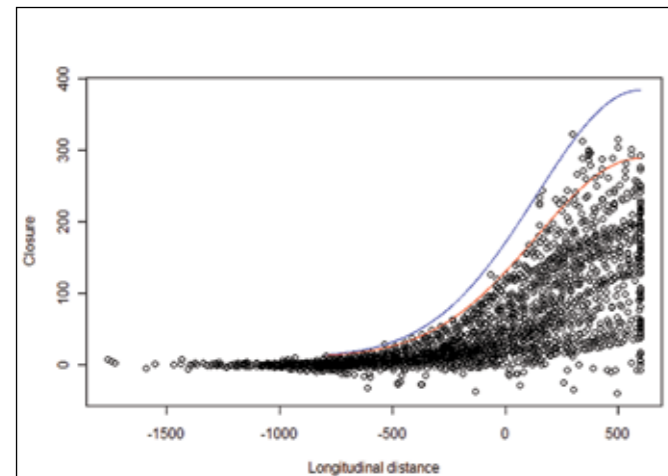
By David Shteinman

The main benefit to engineering practice of using industrial mathematics is in the application of mathematical or statistical thinking to a problem. Industrial mathematics is the field that explores industrial processes and systems, seeks the mathematical or statistical components to explain the underlying structure of a process, and then works to improve or optimise the process under study.

Industrial mathematics, when combined with engineering expertise in a specific domain, deals with complicated or complex problems like optimising the calibration schedule of a nuclear reactor, or modelling and predicting the leakage of sequestered CO<sub>2</sub> in an offshore gas field.

Industrial mathematics has been called a doubly invisible discipline: It is invisible to industry as companies often label the activity of mathematically trained staff as something else, such as modelling, analytics or simply “research”. It is invisible to the academy as university mathematicians do not widely teach industrial mathematics as a specific standalone discipline.

Since 2011 industrial mathematics, and its interface with engineering, have been given a very public boost



Modelling of the effect of underground mining on creek or river beds. The red and blue lines represent the 95th and 99th percentile for incremental closure, conditional on closure being greater than 10mm. It is based on a model using an extreme value theory approach with the longitudinal distance from the mine site as the explanatory variable.

by the establishment of a new industry centre at the University of NSW. The Australian Centre for Commercial Mathematics (ACCM) is using state of the art mathematics and statistics to solve complex engineering problems in the private and public sector.

The majority of the projects performed by the ACCM fall into the area of “complex systems” analysis, modelling and prediction. Despite media emphasis on the growth in data availability, it is the growth in complexity of systems that has fuelled the demand for the ACCM’s services.

The interdisciplinary challenge of dealing with complex systems was verbalised by a senior manager in a road authority who approached the ACCM saying: “We know traditional traffic engineering very well. Now we want to hear from mathematicians and physicists to work with our engineers to solve the big problem of congestion.”

In this case the challenge is reducing road traffic congestion without building new infrastructure and to determine the actual effect of changes made at roading pinchpoints (see article next issue in the roads/roads maintenance feature).

It is most often the case that a project starts not with vast amounts of useable data, but rather with very noisy or in some cases very sparse data. Skill is then needed for data cleaning and filtering before any models can be built.

ACCM projects are found in cases where off the shelf software is either not available or not appropriate. Hence models have to be built “from the ground up”.

For example ACCM is working with Mine Subsidence Engineering Consultants (MSEC) to develop practical statistical methods to predict the magnitude of ground movements due to underground coal mining.

The accurate prediction of ground movements is important both for the mining companies and owners and users of infrastructure and homes close to mine sites.

These movements are known as either ground subsidence, upsidence (in the case of a valley floor) and closure (valley wall). The ACCM has used the approach of empirical modelling using Generalized Additive Models and Extreme Value Theory (EVT). The application of statistical EVT to predict ground movements is a new application.

The EVT-motivated models described the extreme tails of MSEC’s observed strain and curvature data resulted in more credible fits than those based on alternative models.

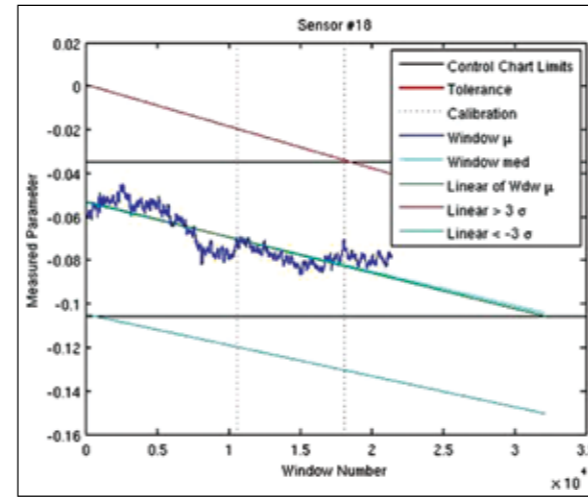


Chart showing the computational monitoring of the sensor drift in OPAL Research Reactor and the possibility of a 3 sigma outlier falling outside the tolerated range for a sensor’s value. This method of displaying and interpreting the sensor data gives a more sensitive detection of sensor drift and allows planning for the next calibration of the instruments.

As a consequence, the predictions of future extreme subsidence are more reliable. The work models the effect of underground mining on creek or river beds, and valley walls. This requires development of models that use regression methods to include relevant explanatory variables.

The aim of the project is to provide mine subsidence practitioners with practical tools that will allow them to ascertain the impact of planned mining activities on the probability of extreme subsidence events in areas with sensitive infrastructure. The research is funded by MSEC and the Australian Coal Association Research Program (ACARP).

Another example is ANSTO’s OPAL Research Reactor, which uses a complex system of sensors for monitoring a large number of performance parameters. As the safety of reactor operations has the highest priority, the importance of scientific approaches for the detection of sensor drift (both on-line and off-line) is significant.

A joint project has just been completed between the ACCM and ANSTO’s Reactor Operations group that showed the validity of extending

calibration intervals of control sensors in a section of the OPAL reactor. The project focused on a section of the reactor which currently undergoes time-based calibration every 18 months.

The frequency of time-based calibration programs is often dictated by the schedule of planned maintenance outages and refuelling outages, with other surveillance and qualitative checks performed more regularly. The benefits associated with less frequent sampling include cost savings, reduced radiation exposure, more targeted interventions and a potential increase in safety.

The accuracy of the detection method is paramount in the optimisation of a sensor calibration routine. The introduction of highly efficient on-line and off-line monitoring procedures for drift detection would lead to better understanding of the sensor degradation behaviour during the critical “At Power” phase of the reactor as well as during “Transition” and “Not At Power” stages.

The project produced a novel technique to find the optimal calibration routine specially designed for smaller, research reactors. The result was a set of recommendations regarding the extension of calibration intervals and confirmation of the validity of the methodology used that generated the new intervals. This was achieved by “stress testing” the methodology using sensitivity, uncertainty and robustness analyses. Optimal calibration intervals contribute to increased lifetime of sensors, increase the useful length of “At Power” status and generally contribute to more efficient operation of the plant. ■

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