Hitting the product development 'sweet spot' with maths

By Ross Jones

Mathematical modelling techniques provide a holistic insight into how products will perform and are proving to be a powerful tool in the pursuit of product innovation. When the design space is large, mathematical modelling can help identify where the 'sweet spot' is and, importantly, it can do it quickly.

A blank sheet of paper and a wish list. That, very often, is where product design starts. As product innovators and developers, we can rapidly fill that page with an array of viable concepts and ideas. The commercial imperative is to swiftly reduce that list down to an optimum solution, and in so doing, provide our clients with a competitive edge.

Scientists, engineers and technologists have access to a great many tools in the product development toolkit. Commercial insights, technical expertise and market sector knowledge are all crucially important. So too are intuition, a flexible approach and a scientifically curious mind.

What mathematics can do is complement both the formal, process-led route to innovation and a scientist's intuition and creativity. What it is particularly good at is considering a wide range of parameters and seeing how together they can influence performance. It gives a holistic overview of how design parameters (the inputs) relate to performance parameters (the outputs). This, potentially, is a very large design space. Through powerful mathematical modelling we are able to identify where the sweet spots are. Client benefits flow from this, including reduced time to market, optimised design, maximised performance and reliability, fewer components and less tooling.

Numerical modelling – usually finite element analysis – is a stock in trade of today's engineer and scientist. It has its limitations though. It will not generally enable or drive the process of innovation. Like laboratory and bench-based work it is also limited by its ability only to consider one parameter at a time. What is needed is a holistic view whereby a wide range of parameters can be considered. This is what analytical (as opposed to numerical) modelling techniques can do very efficiently.

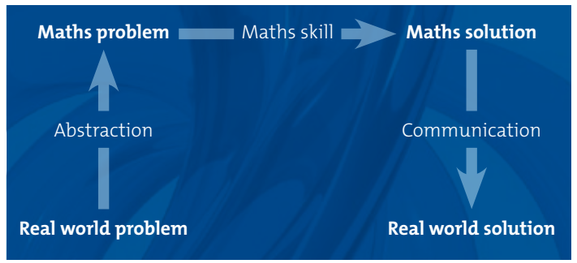
Clients are already benefiting from our competence in analytical modelling – the ability to develop new models, analyse them using mathematical techniques and create computationally efficient simulations. This approach leverages an understanding of underlying scientific principles and delivers deep insight, providing far more than numerical results.

One aspect of analytical modelling – multidimensional data analysis – is particularly important for gaining insight into systems with large numbers of parameters. In the context of modelling, it identifies the combinations of parameters that have the strongest influence on performance.

This is the basis, for example, of rigorous tolerance analysis and experimental design, superseding traditional process-driven methodologies such as Design for Six Sigma or Taguchi analysis. Outside of modelling it provides a powerful tool for characterising empirical data, identifying trends and patterns. We have used it, for example, to create powerful algorithms for condition monitoring and fault analysis.

The mathematician's work is never undertaken in isolation. Sagentia's approach to the business of innovation – known as Collective Technology Wisdom® – is driven by a culture, structure and organisation that ensures that development teams draw on individual and collective experience and adopt a multi-dimensional approach to problem solving. Typically, we will work side by side with electrical and mechanical engineers, physicists, product designers and business specialists at key points in the product development process.

Irrespective of the product development and the mathematical technique used, our involvement in product design and development can be represented by this schematic:



Both the abstraction stage (where we seek to find ways of representing the 'real world' problem using maths) and the communication stage (where we feed back the results of mathematical modelling) involve extensive liaison with the client and the in-house team to ensure that our work remains focused on the real world problem and solution.

Above all else though, it is the existence of a multiplicity of skills within a project team, and the points of interaction that are stimulated as a result, that leads to the creation of richer client solutions. Increasingly, maths is becoming an integral, 'must have' component of this mix, rather than being viewed as a 'nice to have' add-on.

Case studies

Master Meter

The water industry has long sought a low-cost, low-friction encoding register for the automatic reading of water meters. Working with our client Master Meter, we developed Accu*Linx*, a contact-free water meter register. Master Meter's brief called for a register that could fit on a wide range of meter bodies, from small domestic units to street mains. By using a novel mathematical approach, we were able to look at 10^{30} combinations and demonstrate that virtually any meter gearbox for any measurement unit could be manufactured by combining appropriate gears from a set of just seventeen. Engineering intuition led to solutions with more than double this number of gears. Conventional computer programming and a simple numeric approach would not have identified an optimised solution in a reasonable amount of time. By reducing the part count, Sagentia saved Master Meter around a million dollars in tooling costs.

Innovative Technology

For Innovative Technology Ltd, a global supplier of bank note validators, the critical feature of their products is to distinguish real and fake notes with a high level of reliability. When a note is inserted for validation, an array of optical sensors views the note and outputs a sequence of several hundred numbers. This sequence forms the note's digital 'signature'. Traditionally, Innovative Technology used a labour-intensive process of fine tuning their note recognition algorithm for each currency and the latest type of fake bank note. Sagentia developed a novel pattern recognition solution based on multi-dimensional data analysis and geometric modelling. An automated off-line algorithm now analyses sets of notes and generates a compact statistical characterisation of each note in multi-dimensional space that is used by an efficient validator algorithm. The technology, now fully developed and known as SPFTM, has been incorporated into Innovative Technology's bank note validator range of products.

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