Tessella
Technology & Consulting

Bayesian techniques

Bayesian techniques are powerful and highly flexible tools, with applications in the fields of clinical trials, radar tracking, satellite control and many more. As a proven alternative to classical statistics, Bayesian techniques can offer improvements to existing solutions or new solutions to previously unsolved problems. Tessella's combination of wide-ranging experience and mathematical skills mean that we can solve your most complex problems in a highly cost-effective way.

Bayesian techniques can be applied to any problem that involves the extraction of information from data, including data from many disparate sources. Useful information can be obtained from even a single piece of data, with the results becoming more accurate as more measurements are received.

Bayesian techniques offer a formalized way to update existing knowledge in light of new evidence, providing an adaptive learning framework. They are more intuitive than classical statistical techniques, and the results feed more naturally into a decision-making process.

Over the years, Tessella have worked on many applications of Bayesian techniques. We have proven experience in various Bayesian methodologies, and can adapt ideas from different domains to find the best possible solutions to your problems. Some examples of our experience in this rapidly expanding field are given below.

Adaptive Clinical Trials

The drug development process is suffering from increasing costs and a decreasing success rate. Running clinical trials is the most expensive and time-consuming aspect of drug development. Developing better ways to run clinical trials that optimize the learning on those trials whilst minimizing the risk to patients and maintaining the statistical validity of the data is critical to improving the drug development process.

Tessella has been helping to drive innovation in drug development by enabling the deployment of adaptive clinical trials since 1998. Adaptive methods use Bayesian approaches to increase the efficiency of clinical trials by taking account of the data being gathered as the trial runs. Adaptive trials make more effective use of the subjects treated in the trial, and enable better-informed and quicker decisions to be made about the drug being developed.

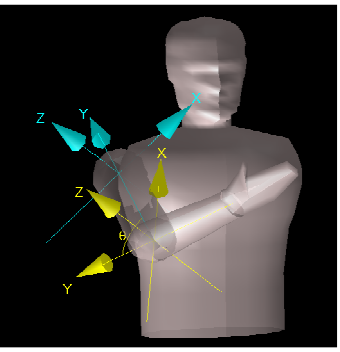
- Adapting the allocation of trial doses and modelling the dose response increase the accuracy of the final estimate of the drug's dose response compared to conventional designs.
- Continuously monitoring the termination criteria allows failing trials to be stopped early, preventing subjects from being exposed to ineffective treatments and saving the sponsor company considerable wasted expenditure.
- Additional assessment criteria, such as the likely cost of bringing the drug to market, can be considered alongside clinical effectiveness.

Radar tracking

Type 45 Destroyer Crown Copyright/MOD

How can radar operators handle the mass of data coming from a modern multi-function radar? In a fast-moving tactical situation the radar system needs to automatically detect, recognize and track friendly and hostile planes, missiles and ships, in an environment which can also include radar returns from cliffs, rain clouds and flocks of birds.

Bayesian techniques allow the system to use each piece of data as it arrives and extract the maximum possible information from each measurement, making them a natural fit to this type of data fusion challenge. Tessella has experience of creating algorithms for a number of radar projects including SAMPSON, a phased-array radar system being built for the UK Royal Navy's new Type 45 Destroyer by BAE Systems Insyte.



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Algorithms developed by Tessella include:

- Bayesian likelihood algorithms for track initiation.
- Optimal association of measurements with multiple tracked targets based on Bayesian maximum likelihood solution.
- Target tracking to perform optimal smoothing of the tracked target state and to predict the associated uncertainties using an Extended Kalman Filter.
- Bayesian filters to track extraneous radar returns and develop clutter maps.
- Bayesian estimator for radar cross section estimation
- Bayesian sensor data fusion algorithms

Public utility networks

Tessella developed an algorithm for a public utility network that focused on efficiency savings by using a Bayesian model to learn the characteristics of the network. The system then optimized the controls of the network to maximize efficiency. The system received intermittent feedback, and used that data to improve the control algorithm. The system is being rolled out nationally and internationally, and the trials have so far shown large efficiency savings compared with a standard system.

Tessella was also commissioned by a consortium of water companies to implement a Bayesian asset model designed by a leading statistician. This model allowed them to manage their assets with less frequent inspections that would be required by a classical statistical method, a significant advantage given the large number of assets, and the inaccessibility of many of them. The system can also be used to assess and predict asset value for financial purposes.

Inertial navigation and body motion

How can we track the position of a person moving through a building? How can doctors measure the bending of a person's joints as they move around? Tessella has shown that it is possible both to track a person as they move, and to follow the bending and flexing of each joint, by combining gyroscopes and accelerometers with an advanced Kalman filtering technique. This Bayesian method maintains a continually-updated optimal estimate of position and orientation, and allows us to exploit the additional constraints of the human body to improve the results.

An inertial navigation system attached to a shoe, belt or helmet could be used to improve the safety of emergency personnel, particularly inside buildings where GPS signals are generally unreliable. The body motion measurement techniques, developed in conjunction with the University of Salford's Institute for Health and Social Care Research, will prove invaluable in physiotherapy for rehabilitation after injuries, for developing technologies to help stroke patients, and in training for elite athletes. These sensors are cheaper and easier to set up than a camera-based system, and can be used 'in the field', not just in carefully set up labs, to measure motion in real-life scenarios.

Herschel *©ESA – AOES Medialab*

Spacecraft pointing accuracy

Virtually all satellite missions must meet specific requirements for the accuracy with which they point in the right direction. For scientific missions such as the Herschel telescope, even miniscule errors in pointing can have a large impact on the results. The orientation of a satellite has many possible sources of error due to movement of the satellite and uncertainty in the sensor measurements. All these errors contribute to the overall error in the spacecraft instruments.

The European Space Agency (ESA) developed a rigorous set of statistical algorithms to capture individual sources of error and combine them to give overall performance. ESA's recommended approach is encapsulated in the *Pointing Error Handbook*, originally written by staff now at Tessella, which can be used by companies developing spacecraft to construct detailed pointing error budgets. Central to the methodology is the use of Bayesian methods to update the probability distributions of the individual errors when new information is received, in order to make optimal use of available information. These probability distributions can then be recombined to obtain a new estimate of the distribution of the overall error.

ESA also commissioned Tessella's Analytic Pointing Performance software tool, which fully implements the Bayesian methodology from the *Pointing Error Handbook* to allow pointing performance to be calculated.

2D gel mapping

Tessella worked with an imaging expert to develop a Bayesian algorithm for a biotech company to first align and then analyze the differences in 2D protein peptide maps resulting from a 2D chromatography process. This allowed the automation of what had been a labour-intensive process.

The accuracy of the system, and the reduction in the amount of manual work required have drastically improved the efficiency of identifying potential drug candidates. This has led to a much higher throughput of studies and, therefore, an increase in the rate at which drug candidates can be identified and subsequently brought to market.

Conclusion

Bayesian techniques have many advantages over the methods of classical statistics. Bayesian methods can be used to develop adaptive systems that respond to real-time data input or improve their performance over time. Bayesian methods can also be used to estimate the future state of a system and make control decisions based on those estimates.

Tessella's experience of using Bayesian techniques in a wide range of applications allows us to exploit solutions from many domains, and apply our mathematical expertise to solve your problems.

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