The aim of the honours projects is for the student to gain experience with advanced computational techniques, especially, the techniques which are used to solve high-dimensional problems. A major challenge is the curse of dimensionality and methods to address this challenge using sparse grids will be used.

The projects include components of mathematical modelling and computational science. Other projects than the ones suggested are also possible, and interested students are welcome to discuss their own ideas. The projects should involve numerical analysis and more than four-dimensional problems. Some basic understanding of probability including conditional probabilities is required.

The student needs to have taken an advanced course in numerical linear algebra (MATH3512) and have a good background in analysis. It is suggested that higher numerical analysis courses (MATH3352) are taken while doing the project. It would be an advantage if the student has passed Analysis I and II at least.

Our projects cover computational methods used in biology, chemistry, physics, finance and machine learning. They prepare applied and pure mathematicians for collaborative work with scientists and engineers. The topics may lead to research into the challenging area of high-dimensional numerical analysis using high-performance computing and could prepare for further research in this area at the level of a PhD.

Stochastic models in molecular biology

Modern biology and bioinformatics are uncovering large networks of interacting proteins and other substances. The aim of this project is to take a special example of such a network, derive the underlying Markov model - the stochastic master equations - and develop and analyse numerical methods to solve them. The student can suggest a particular system, earlier projects have discussed the lambda phage, general gene regulatory networks and a current (PhD) project is dealing with the cell cycle. The objective of the project is to work towards getting a tool which will allow answering questions like: "If the level of protein A is given at time t_1 how likely is it that protein B will have a certain level at time t_2?"

Learning conditional probability distributions

The project should develop techniques based on ideas from approximation theory (sparse grids), graphical models (like Bayesian networks) to

infer high-dimensional probability densities and their properties from data. Along the way, the student will get familiar with random fields, their corresponding probability measures and the consequences of the fact that these measures have no density. Possible machine learning approaches
to consider include Bayesian techniques, the maximum a posteriori method and methods based on various divergences including the Bregman divergence. This project may involve working with researchers from computer science.

Analysing plasma data

Large amounts of time series data have been collected by the Plasma physics
group at the ANU. The aim of this project is to develop numerical techniques based on the wavelet packet transform to analyse the data. This work has a datamining aspect and builds on some earlier work where wavelets were used for pre processing. It also will be able to make use of results from a PhD done recently at the RSPhysSE at the ANU.