Mentors		
Adachi, Jose	jadachi@houston.oilfield.slb.com	Schlumberger
Bingham, Derek	bingham@sfu.ca	SFU
Hjorth, Poul	p.g.hjorth@mat.dtu.dk	Technical U. of Denmar
Promislow, Keith	kpromisl@math.msu.edu	Michigan State U.
Pyke, Randall	pyke@sfu.ca	SFU
Restrepo, Juan	restrepo@physics.arizona.edu	U. of Arizona

Nine Tailors - Effective Ringing of a Church Bell

Mentor: P.G. Hjorth,
Department of Mathematics, Technical University of Denmark

The task is to point to effective methods of controlling the motion of a heavy church bell, through a force that can only be applied during a part of the bell period. Furthermore the period of the bell is to be controlled and changed in a precise manner, to accommodate the traditional change ringing. Some data from real bells is available.

Keywords: Classical mechanics, control theory.
Supplementary/entertaining reading: Dorothy L. Sayers: "Nine Tailors" (1934).
See also: http://en.wikipedia.org/wiki/Change_ringing

Combining Model and Data in the Estimate of Mean History

Mentor: Juan Restrepo
University of Arizona

How do you control a fast craft that's about to land on Mars, when the signals coming back to Earth from the probe take precious fractions of a minute? How do you make a weather forecast when you have data and models which are both plagued by errors in modelling and in the data gathering itself? How do you tune parameters in a financial model, given that there are past records of the market? can you develop an efficient way of cleaning up a noisy image, given that you know certain constraints about the shapes and forms to be found in the image?

A commonly used strategy in these problems is to use recursive least squares (Kalman Filtering or its cousins). However, methodologies that have been developed for linear dynamics and/or Gaussian statistics often fail on nonlinear/non-Gaussian problems.

We will first explore using Bayesian techniques, combined with accelerated sampling to formulate this "data assimilation problem" as a path integral. We will test this method, first on a toy problem which is known to cause failure in traditional estimation techniques, we will then try the methodology on a real problem from engineering, financial prediction, or from epidemiology, comparing the path integral approach to other more traditional approaches.

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Queuing network simulation analysis: developing efficient simulation methodology for complex queuing networks

Mentor: Derek Bingham
Simon Fraser University

Simulation can provide insight to the behavior of a complex queuing system by identifying the response surface of several performance measures such as delays and backlogs (i.e., how the performance measures vary according to the system input rates). However, simulations of large systems are expensive both in terms of CPU time and use of available resources (e.g., processors). Of particular interest is understanding the boundary between "good" and "bad" performance of the system. Specifically, we are interested in estimating this boundary given some existing simulation runs and also determining future trials which will optimally improve the estimator.

Cooling of a Logging Tool by Drilling Mud Circulation*

José I. Adachi†

June 1, 2006

The most commonly used setup in oilfield drilling operations consists of a drillbit and a bottomhole assembly (which sometimes includes devices such as logging and steering tools, stabilizers, etc.) which are connected to the surface via a drillpipe. In order to remove the detritus generated during the drilling operation, and to cool down the bit and the assembly (as well as to ensure the stability of the wellbore until casing is installed), a very viscous fluid called the "drilling mud" is pumped down through the drilling pipe, enters the wellbore via nozzles located at the bit, and returns to the surface through the annulus between the borehole walls and the drillpipe (see Figure 1).

Occasionally, the drilling operation has to stop due to mechanical or logistic problems. During those "dead times", the operators usually let the mud circulate at a much slower rate than during active drilling. However, the electronic components of the bottomhole assembly must be maintained below a given threshold temperature, to keep them from "frying". Assuming that the rock temperature, the fluid temperature at a certain depth, the thermal properties of the rock, fluid and pipes, and all the dimensions are known, the question is what should be the minimum rate that should be kept to avoid the temperature at the bottomhole assembly to raise above such threshold temperature.

*Problem proposed for the 9th Graduate Industrial Mathematics Camp (GIMMC), Simon Fraser University, Vancouver, June 21-24, 2006.

†Schlumberger DCS, Houston, TX, USA. E-mail: jadachi@slb.com.

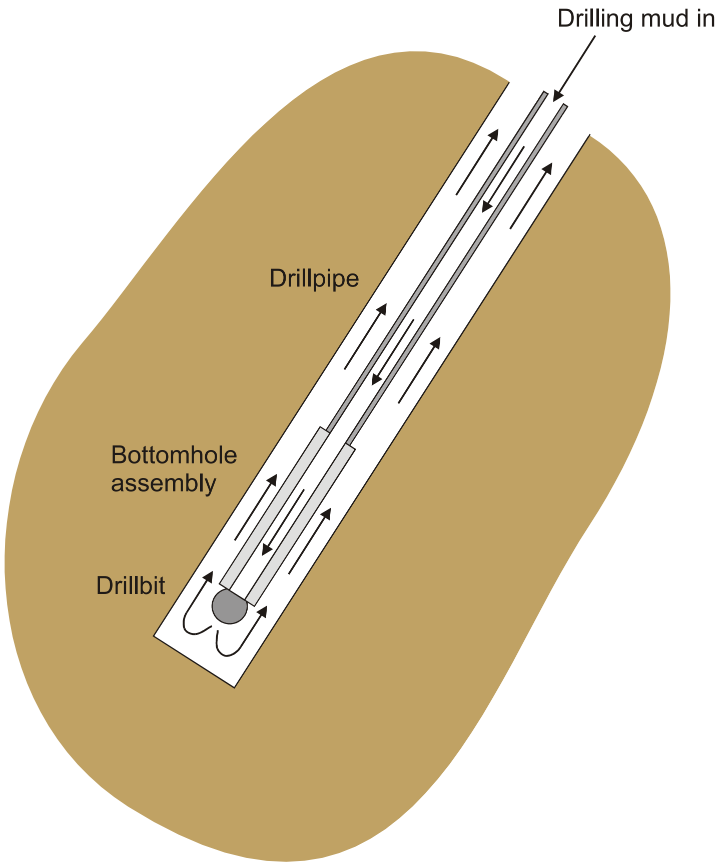


Figure 1: Schematic for Problem 1.

Controling Nitrogen Cross-Over in a Recirculating PEMFC

Keith Promislow

Polymer Electrolyte Membrane fuel cells (PEMFC) convert the chemical energy of the oxidation reaction

$$O_2 + 2H_2 \to 2H_2O$$

into useful elecrical energy by dividing the reaction into two steps. The Hydrogen oxidation reaction (HOR)

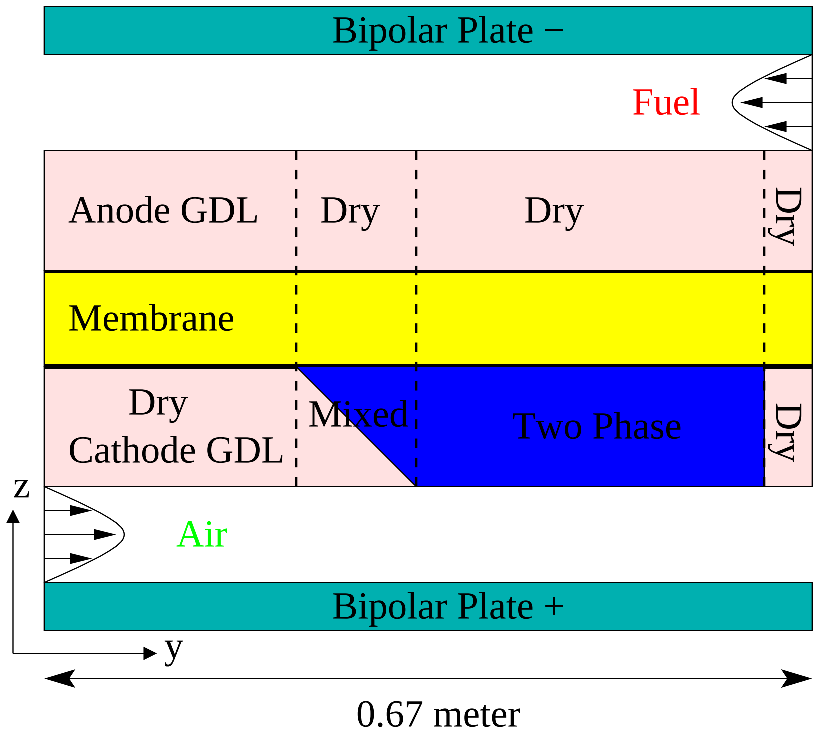
$$H_2 \to_{\text{Pt}} 2H^+ + 2e^-$$

is completed on the anode, while the oxygen reduction reaction (ORR)

$$O_2 + 4H^+ + 4e^- \to_{\text{Pt}} 2H_2O$$

takes place on the cathode. The anode and cathode are separate by an membrane which is a good protonic conductor and a poor electrical conductor, and is more or less impermeable to gas phases. The voltage, and power, produced by the fuel cell depends upon the concentrations of the reactants, particularly the oxygen and protons at the cathode.

In typical operation hydrogen gas is blown down a flow field on the anode side of the cell, while air (oxygen+nitrogen) is blown down a flow field on the cathode side. Roughly 10-20% of the hydrogen which enters the anode flow field is not consumed and one wishes to recirculate this fuel to increase effeciency. However nitrogen has the tendancy to cross over the membrane from the cathode to the anode and contaminate the hydrogen effluent. The goal is to develop a model for the PEMFC operation which includes nitrogen cross over, and devise a strategy to mitigate its impact.


Bipolar Plate −
Fuel
Anode GDL
Dry
Dry
Dry
Membrane
Dry
Cathode GDL
Mixed
Two Phase
Dry
z
Air
Bipolar Plate +
y
0.67 meter

Modelling Forest Fires with Percolation

Graduate Industrial Mathematical Modelling Camp, June 2006
Presented by R. Pyke, Simon Fraser University

Suppose we have a lattice (eg., $\mathbb{Z}^n$ or some subset thereof) where each lattice site is either occupied or not depending on a probability p. A *cluster* is a group of neighboring occupying sites. Percolation theory deals with the number and properties of these clusters.

Now suppose the occupied sites evolve (in discrete time steps) according to certain rules which depend (among other things) on the properties of the neighboring sites, ambient properties of the lattice at that location, and perhaps time-dependent effects. The evolution of the system will vary according to the initial distribution of occupied sites.

Examples of phenomenon that can be modelled by this method are forest fires and epidemics. In the case of forest fires each site corresponds to a location of a possible tree, and in the case of epidemics each site corresponds to a person or community of people. After the sites are populated, a fire is initiated. A critical probability p_c exists at which percolation is possible for $p \geq p_c$; the entire forest is burned or the entire population becomes infected. Another way to say this is that as p increases, the maximum cluster size (connected occupied sites) increases and becomes infinite at p_c. The duration of the forest fire (or epidemic) peaks at the critical probability, and is more pronounced as the lattice size increases. This effect is referred to as a phase transition in physics.

Our task will be to develop a model for forest fires that includes features such as topography, wind and fuel. Through simulation we will examine various evolutions and analyze how the parameters of the model affect the behaviour (such as length of duration of the fire). We will then use this model to investigate fire fighting/prevention strategies.

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