Modelling, advice and public policy

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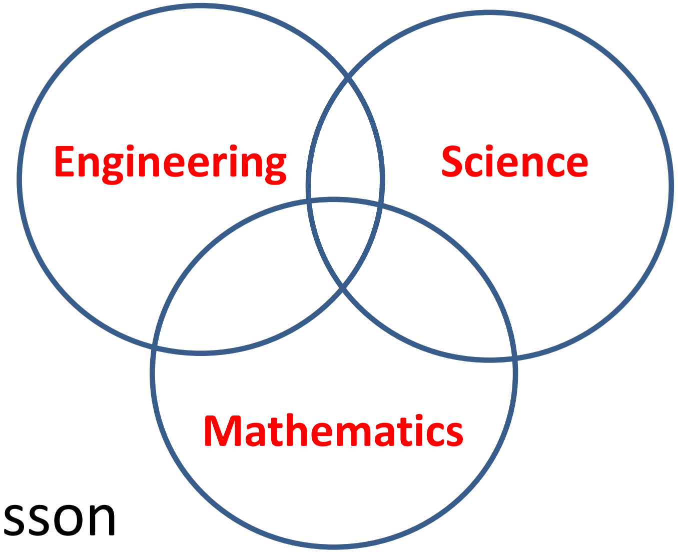
10 December 2014

The Scottish Government

University of Glasgow
VIA VERITAS VITA

My background



Supervisor^{8} = Poisson
Supervisor^{9} = Lagrange
Supervisor^{10}= Euler

Erdos number = 4

Mathematical models

A key part of science/engineering

Abstraction

Detail we need in order to ask and answer questions

Representation

Faithful and efficient

Role of Scientists

Must ensure that

- **Key decision makers can be confident that evidence is robust and stands up to challenges of credibility, reliability and objectivity**

- **Key decision makers can be confident that the advice derived from the analysis of the evidence also stands up to these challenges**

- **The public are aware, and are in turn confident, that such steps are being taken - role for social scientists**

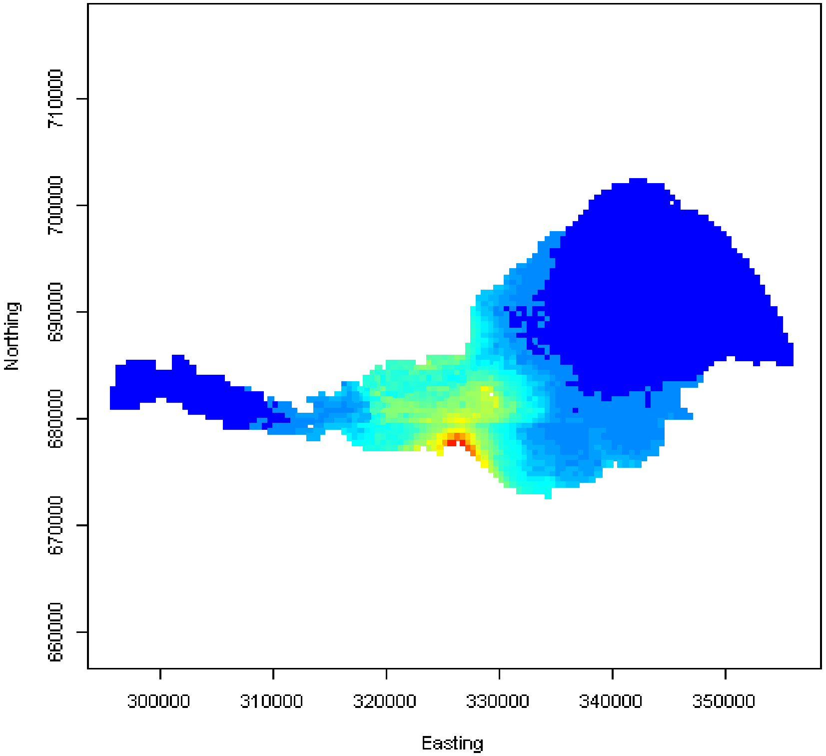
Four examples

Variety of problem domains and mathematics

1. Animal movements

- **Protection of breeding seabirds (regulation)**
- Identification of nesting and feeding sites
- Analysis of flight paths of individual birds
- Follow birds by boat (!)

Common tern population at Leith: usage of Firth of Forth (red high, blue low)



Maths: Integrated Nested Laplace Approximation (INLA)

- approximate Bayesian inference for latent Gaussian models (replaces MCMC)
- for estimation of population size trajectories b

2. Strategic transport model

For transport supply and estimates of transport demand

- covers whole population of Scotland
- details the choices on how, where, why and when people travel
- links with an interactive land-use
- for broad option identification, ranking and scheme/policy appraisal
- capable of modelling traveller responses to road tolling/pricing
- *does not* model the operation of junctions or congestion

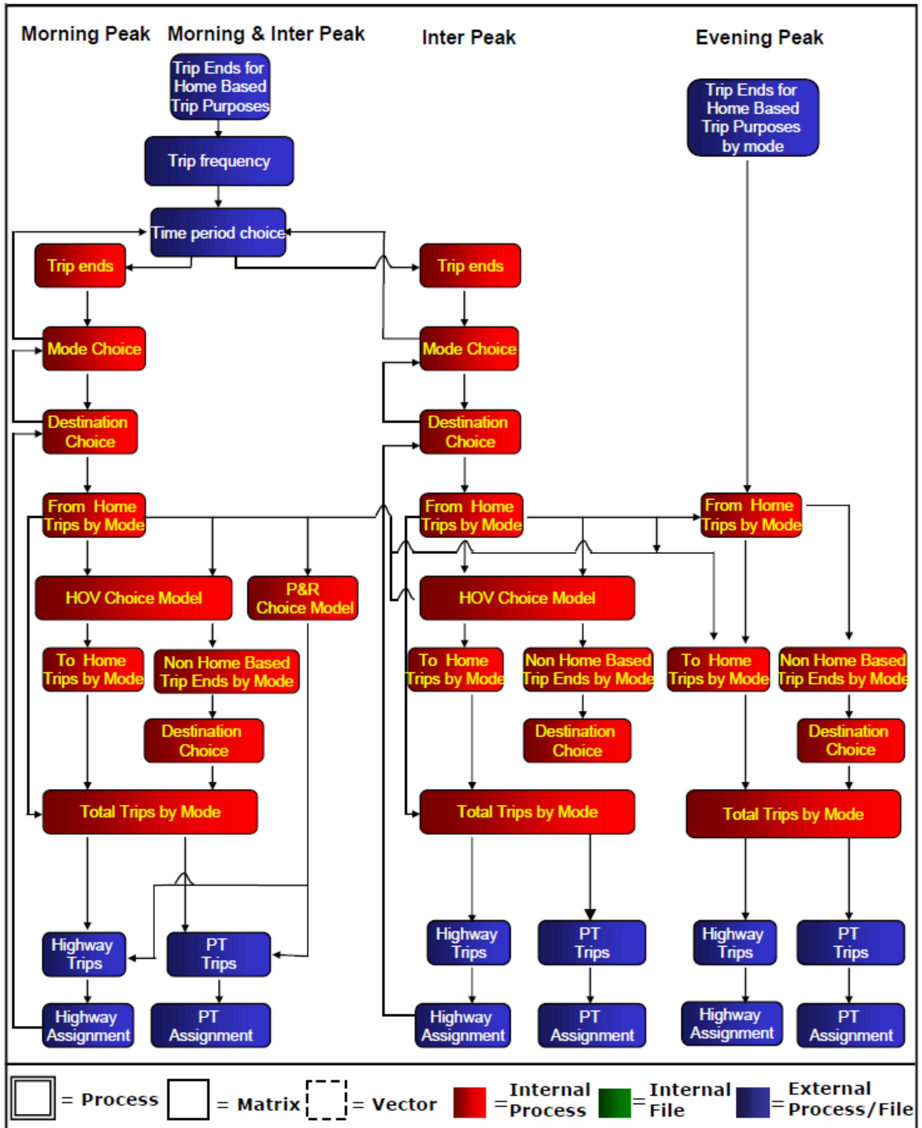


Figure 1: Time Period Demand Model

Model segmented by
- No Car Households
- 1 Car 1 Adult Households
- 1 Car 2 Adult Households; 2+ Car Households

Journey purposes:
- home-based work
- home-based employer's business
- home-based other
- home-based education
- non-home-based employer's business
- non-home-based other

2. Strategic transport model

Policy assessments

e.g.

- Forth Replacement Crossing
- Edinburgh Glasgow Rail Improvement Programme
- Carbon Account for Transport

Maths: “gravity” model

Amount of travel between two areas

: proportional to population, numbers of jobs, schools, offices etc

: inversely proportional to distance

A gravity model:

$$T_{ij} = K_i K_j T_i T_j f(C_{ij})$$
$$\sum_j T_{ij} = T_i, \sum_i T_{ij} = T_j$$
$$K_i = \frac{1}{\sum_j K_j T_j f(C_{ij})}, K_j = \frac{1}{\sum_i K_i T_i f(C_{ij})}$$

where

- T_{ij}= Trips between origin *i* and destination *j*
- T_i= Trips originating at *i*
- T_j= Trips destined for *j*
- C_{ij}= travel cost between *i* and *j*
- K_i, K_j= balancing factors solved iteratively

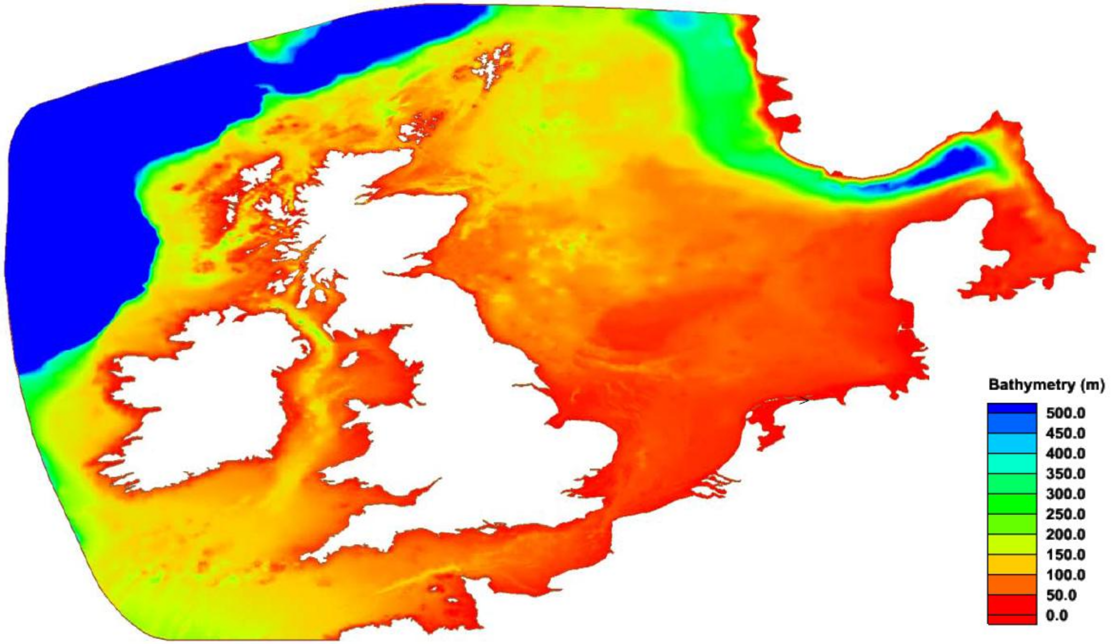
- f= distance decay factor

3. Bathymetry

3. Bathymetry

Fisheries Policies and Monitoring

Scottish Shelf Model



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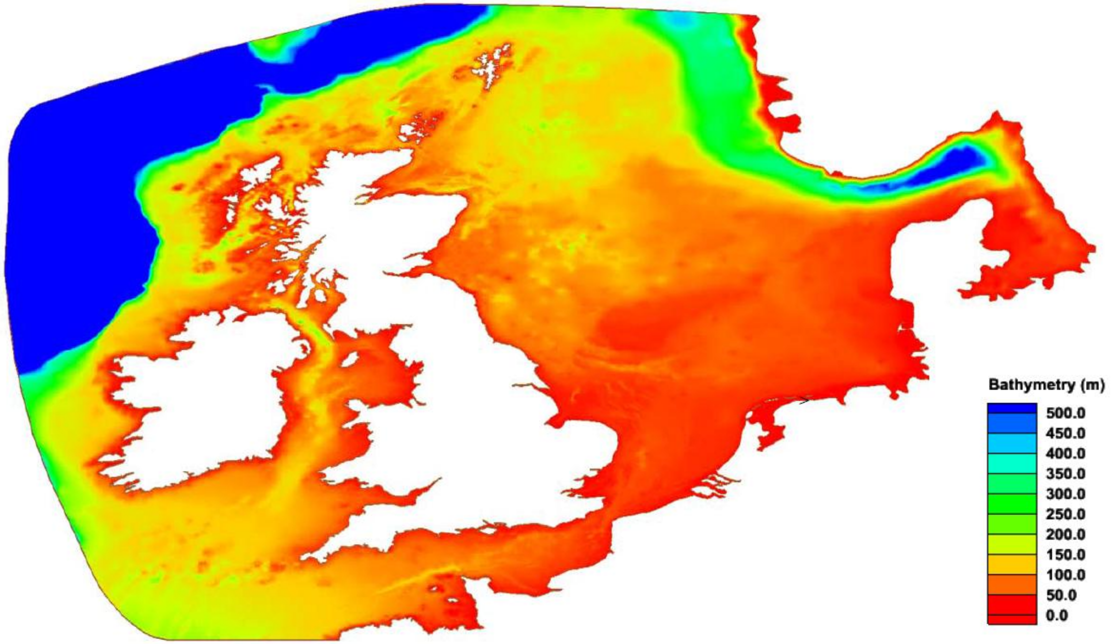
Maths: PDEs

Hydrodynamics
Scottish Shelf Model



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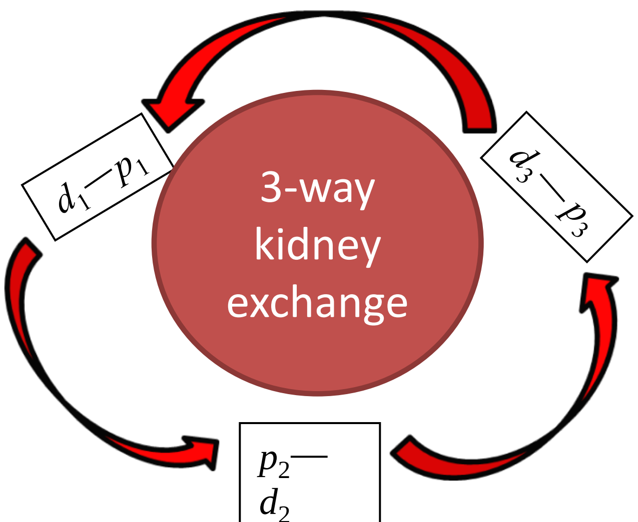
4. Kidney exchange

5881 kidney patients on active transplant list (March 2014)

- A patient with a willing but incompatible donor can swap their donor with that of another similar patient
- NHS Blood and Transplant: National Living Donor Kidney Sharing Schemes to find optimal sets of kidney exchanges

Algorithm developed at University of Glasgow (used since July 2008)

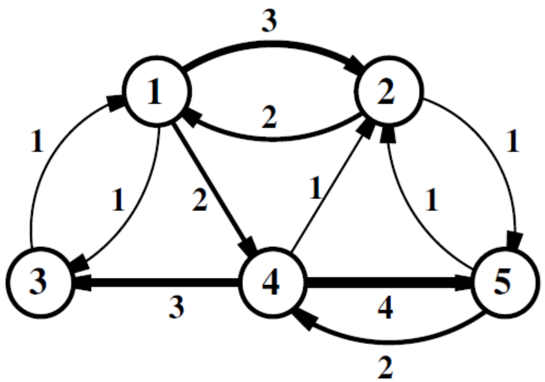


- Algorithm uses integer programming to solve NP-hard optimization problem
- Transplants resulting from scheme
  - Pairwise exchanges (two d-p pairs): 63
  - 3-way exchanges (three d-p pairs): 45
  - Short chains (altruistic donor + one d-p pair): 41
  - Total transplants: **343**

Maths: Graph theoretic model and integer linear programming

max cx
s.t. $Ax \leq b$
and $x_i \in \{0, 1\}$

where



$$A = \begin{bmatrix} 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}, \quad b = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}, \quad x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \end{bmatrix} \text{ and}$$

$$c_s = \begin{bmatrix} 2 & 2 & 2 & 2 & 3 & 3 & 3 \end{bmatrix} \text{ if maximum size}$$

D.F. Manlove and G. O'Malley, Paired and altruistic kidney donation in the UK: Algorithms and experimentation, ACM Journal of Experimental Algorithmics, 2014

My advice about advice

1. Be an expert.
2. Be an advocate for your discipline, and your institution.
3. Speak for the science, not the scientists (unless that is your job).
4. Solve their problems, not yours. Listen to the problem, and then offer solutions. Be honest, the solution for the problem might not be your favourite one, or the one you have developed, or an area where you have expertise.
5. Be prepared to work with people for whom your area, e.g. science/arts/humanities/law … is not crucially important.
6. Think about their context, e.g. a politician has to convince voters, who are subject to many voices and pressures.
7. Advice for policy should be: evidence-based, selfless, innovative, work from first principles.
8. Be clear in your mind about the difference between X for policy, and policy for X. E.g. science for policy, and policy for science.

Thank you