APPLIED URBAN MODELLING 2018

Remembering Lionel March

Configuration, Information & Spatial Interaction

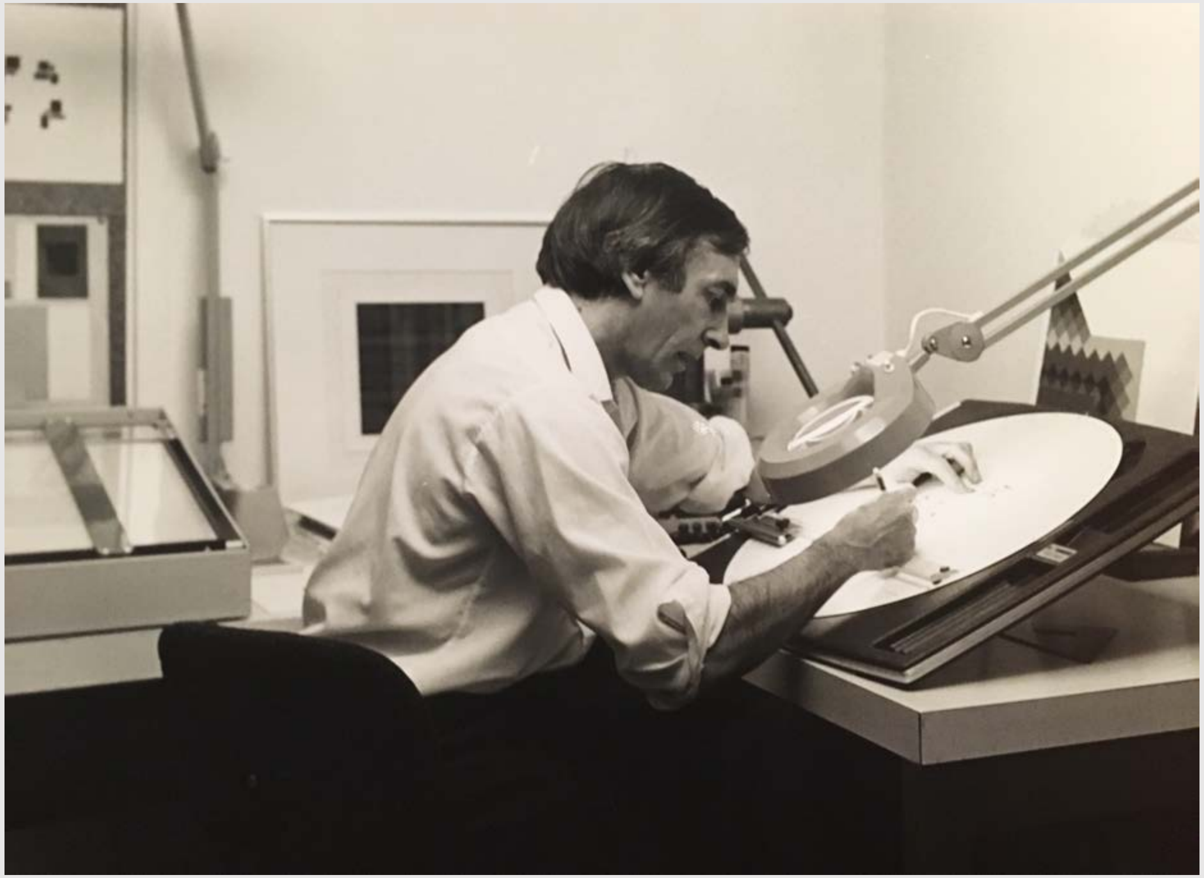
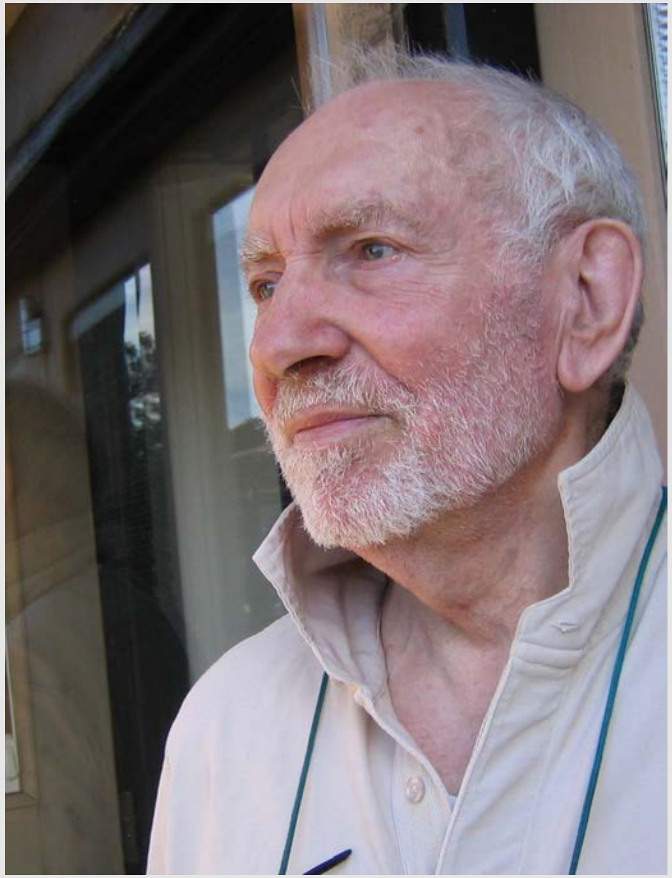
Michael Batty

Centre for Advanced Spatial Analysis, CASA-UCL

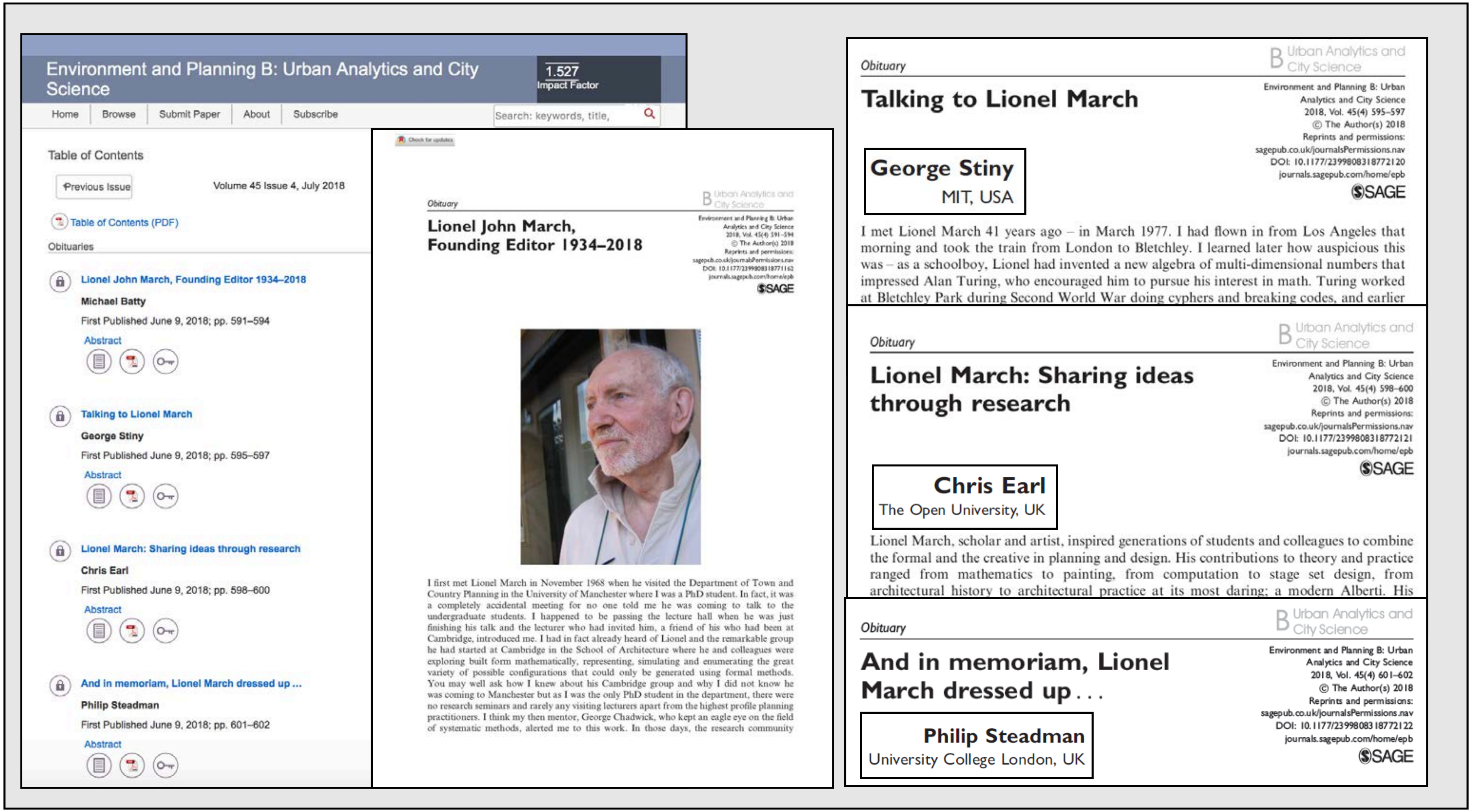
June 28th 2018

m.batty@ucl.ac.uk

@jmichaelbatty

In Memoriam: Lionel March: 1934 – 2018



Environment and Planning B: Urban Analytics and City Science

1.527
Impact Factor

Home | Browse | Submit Paper | About | Subscribe

Search: keywords, title,

Table of Contents

Previous Issue

Volume 45 Issue 4, July 2018

Table of Contents (PDF)

Obituaries

Check for updates

Obituary

B Urban Analytics and City Science

Environment and Planning B: Urban Analytics and City Science
2018, Vol. 45(4) 591–594

Reprints and permissions: sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/2399808318771162
journals.sagepub.com/home/epb
SAGE

Lionel John March, Founding Editor 1934–2018

I first met Lionel March in November 1968 when he visited the Department of Town and Country Planning in the University of Manchester where I was a PhD student. In fact, it was a completely accidental meeting for no one told me he was coming to talk to the undergraduate students. I happened to be passing the lecture hall when he was just finishing his talk and the lecturer who had invited him, a friend of his who had been at Cambridge, introduced me. I had in fact already heard of Lionel and the remarkable group he had started at Cambridge in the School of Architecture where he and colleagues were exploring built form mathematically, representing, simulating and enumerating the great variety of possible configurations that could only be generated using formal methods. You may well ask how I knew about his Cambridge group and why I did not know he was coming to Manchester but as I was the only PhD student in the department, there were no research seminars and rarely any visiting lecturers apart from the highest profile planning practitioners. I think my then mentor, George Chadwick, who kept an eagle eye on the field of systematic methods, alerted me to this work. In those days, the research community

Obituary

B Urban Analytics and City Science

Environment and Planning B: Urban Analytics and City Science
2018, Vol. 45(4) 595–597

Reprints and permissions: sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/2399808318772120
journals.sagepub.com/home/epb
SAGE

Talking to Lionel March

George Stiny
MIT, USA

I met Lionel March 41 years ago – in March 1977. I had flown in from Los Angeles that morning and took the train from London to Bletchley. I learned later how auspicious this was – as a schoolboy, Lionel had invented a new algebra of multi-dimensional numbers that impressed Alan Turing, who encouraged him to pursue his interest in math. Turing worked at Bletchley Park during Second World War doing cyphers and breaking codes, and earlier

Obituary

B Urban Analytics and City Science

Environment and Planning B: Urban Analytics and City Science
2018, Vol. 45(4) 598–600

Reprints and permissions: sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/2399808318772121
journals.sagepub.com/home/epb
SAGE

Lionel March: Sharing ideas through research

Chris Earl
The Open University, UK

Lionel March, scholar and artist, inspired generations of students and colleagues to combine the formal and the creative in planning and design. His contributions to theory and practice ranged from mathematics to painting, from computation to stage set design, from architectural history to architectural practice at its most daring; a modern Alberti. His

Obituary

B Urban Analytics and City Science

Environment and Planning B: Urban Analytics and City Science
2018, Vol. 45(4) 601–602

Reprints and permissions: sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/2399808318772122
journals.sagepub.com/home/epb
SAGE

And in memoriam, Lionel March dressed up . . .

Philip Steadman
University College London, UK

You can download the
Obituaries from

http://spatialcomplexity.info/files/2018/06/Lionel-March-Obituaries-EPB.pdf

You can download this presentation
as a PDF from

http://spatialcomplexity.info/

I want to talk about Lionel's contribution of course and I will do this in relation to our work together when we were both in Engineering at the University of Waterloo, me from 1974–1975 and Lionel from 1974–1976.

I am going to talk about our work on using Bayesian methods in thinking about spatial interaction. We published three papers on this idea and I will tell you about them. I will divide my talk into three parts

1. *the ideas, the methods;*
2. *then about what Lionel and myself did with them;*
3. *finally a suggestion that there is much unfinished business;*

And we can push these ideas into those about more generic data-driven modelling, about scientific explanation

The Ideas: Prior and Posterior Probabilities

In our world, the idea that we already have information about how we might explain any phenomenon before we set about actually explaining it, is generic.

We can encode this in the notion of *Prior Probabilities* – of some information explaining the location, say, of an activity – and then modifying this probability with some theory of how the activity locates in a place. This is the *Posterior Probability* and new information is introduced to update the prior to the posterior.

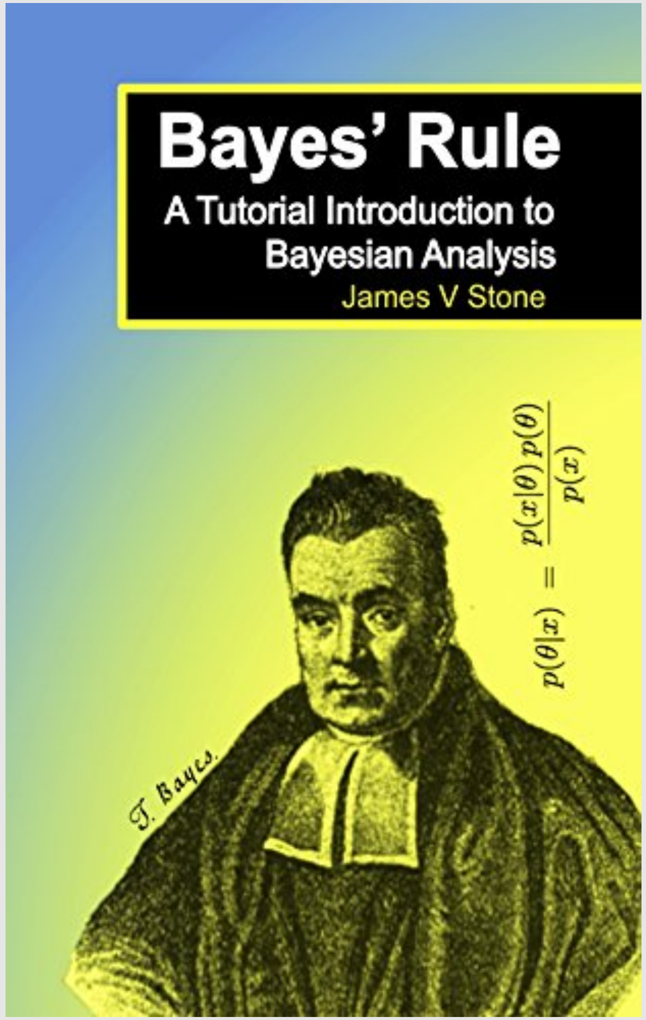
There is a well-defined theorem to represent this and it is called *Bayes theorem*, sometimes rule and it is an ever more popular.

Before I tell you about how Lionel and myself embarked on this problem, I will state Bayes' rule so that you have an idea of the formality of all this.

$$p(\theta \mid x) = \frac{p(x \mid \theta)}{p(x)}\, p(\theta)$$

$$\begin{pmatrix} \textit{posterior} \\ \textit{probability} \end{pmatrix} = \begin{pmatrix} \textit{likelihood} \\ \textit{ratio} \end{pmatrix} \begin{pmatrix} \textit{prior} \\ \textit{probability} \end{pmatrix}$$

The posterior observed event θ is and the prior observed event is x



In fact, we can derive Bayes equation quite naturally from a simple equality

$$p(\theta \mid x)\, p(x) = p(x \mid \theta)\, p(\theta)$$

θ Is **that**; x is **this**;

This says: the probability of **this** given **that** occurring, times the probability of **that** occurring is equal to the probability of **that** given **this** occurring, times the probability of **this** occurring.

This is both intuitively obvious and confusing as much of probability theory is.

Let us now reformulate this simple relation in the algebra and notation that we understand here in spatial modelling

We can write the posterior as equal to the product of the likelihood ratio times the prior probability as

$$P_i = \Lambda_i Q_i$$

Where the probabilities are normalised as $\sum_i P_i = 1 \quad \sum_i Q_i = 1$

Now we can write the equation where we identify the normalisation directly as

$$P_i = Z L_i Q_i$$

Where

$$Z = \frac{1}{\sum_i L_i Q_i} \quad ; \quad P_i = \frac{L_i Q_i}{\sum_i L_i Q_i}$$

Different Kinds of Prior Probabilities

Essentially the prior probability is turned into a posterior by adding new information which is essentially the model - - we can think of this as what we have already Q_i times the new information which is what we hypothesise.

Let us look at what we have already

- The simplest Q_i is say something like the capacity or area of land or the number of houses say in residential location – we need these before we can occupy them with residents
- We could also assume a null hypothesis

$$Q_i = 1/n \qquad and \qquad \sum_{i=1}^{n} Q_i = 1$$

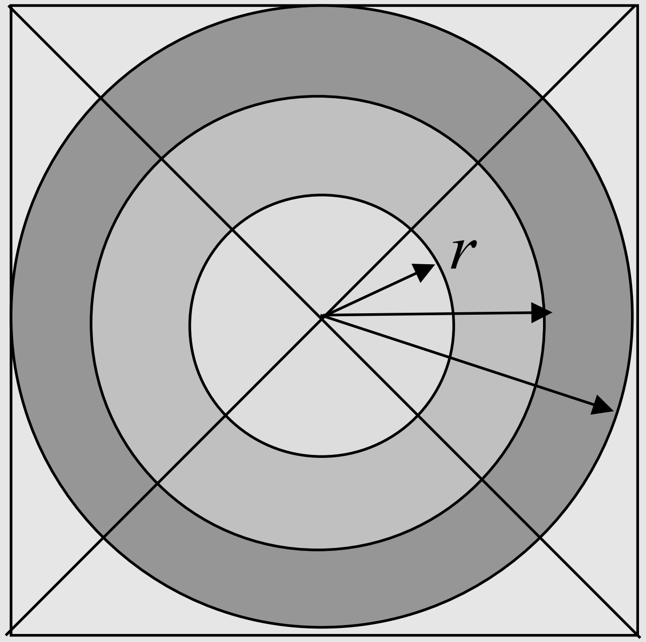
And this means that the prior has no effect

- We might also think of the prior as some sort of geometric default – in other words due to the effect of space. Let us now assume that if an individual travels from an origin to ever further destinations, the number of possible destinations increases in proportion to the distance travelled and this the probability of ending at one of those destinations declines inversely with distance r_i

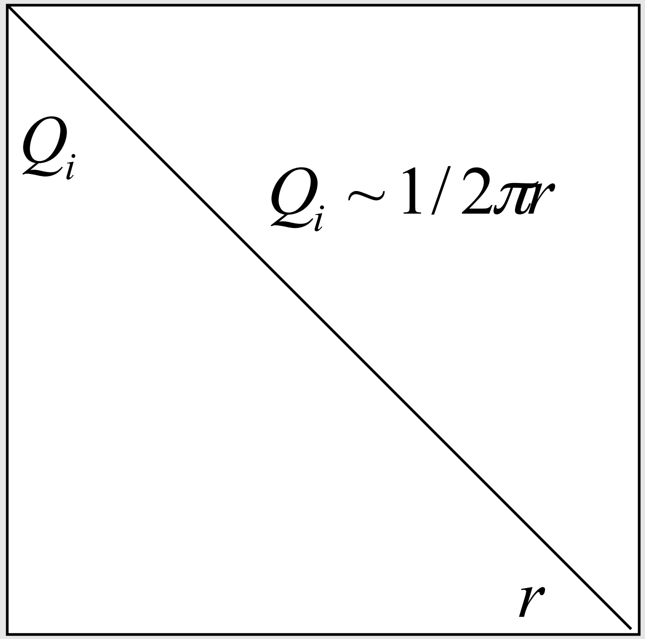
  We thus have to factor out this effect – in other words it already exists and this we might define the prior as

$$Q_i \approx 1/r_i = r_i^{-1} / \sum_i r_i^{-1}$$

We can articulate this effect in the following picture



$$A = 2\pi r^2$$
$$dA/dr = 2\pi r$$



This is related to James S Coleman's *Method of Residues* which I will recount below as one of our applications

Now here is a more controversial idea – the model is the data

- We might think of the prior as the data and thus the model becomes updating the data into the 'data' – in short the best model we have is the data. This sounds crazy but it helps us to think of the model as an update of what we know and we know the data. We can this write the model as

$$Q_i = \frac{Q_i}{\sum_i Q_i} = P_i = \frac{L_i Q_i}{\sum_i L_i Q_i}$$

- In fact if we update the data by changing some aspect of it, we do what Fratar did in 1954 – and also what various people have done with respect to using biproportional factoring to update I-O and trip matrices

- We can now introduce our last idea of the prior – as an updating of the data through time – or using the model as the data to produce another model – through real time or even through 'model time'. We write the posterior-prior relation as

  $$P_i(t+1) = Z(t)\,L_i(t)\,P_i(t) = \Lambda_i(t)P_i(t)$$

  where the prior is now the model prediction at the previous time interval; and where the initial model is the prior data

  $$P_i(t) = Q_i$$

  Then by recursion we can express the posterior as a function of the original prior and the sequence of likelihoods

$$P_i(t+n) = \Lambda_i(t+n-1)P_i(t+n-1)\,...\,P_i(t+1)P_i(t)$$

We can now simplify this as

$$P_i(t+n) = \Lambda_i(t+n-1)\ldots\Lambda_i(t+1)\Lambda_i(t)P_i(t) = P_i(t)\prod_{\tau=1}^{t}\Lambda_i(t)$$

Lionel in his inimitable way called this a *Bayes Chain*. I don't think anyone else has called it this but he did; and I think we only referred to it once.

- There is one last thing before I tell you what we did together. In fact what we did involves what I have just been talking about but the big unifying idea involves using information theory to derive these models.

  In short if you define information as Kullback & Leibler defined it in 1951, not long after Shannon, the idea is that information is the difference between the prior and the posterior i.e.

Now information is thus defined as

$$I = \sum_i P_i \log \frac{P_i}{Q_i}$$

And we can minimise this subject to all the information that we think is relevant to the model; but first let us look at the formula when $Q_i = 1/n$

$$I = \sum_i P_i \log \frac{P_i}{1/n} = \log n + \sum_i P_i \log P_i = \log n - H$$

Now let us minimise this and we form the Lagrangian

$$\min L = \sum_i P_i \log \frac{P_i}{Q_i} - \mu(\sum_i P_i - 1) - \lambda(\sum_i P_i \, r_i - R)$$

We get the standard model but it has a prior probability now

$$P_i = \exp(-\mu)\exp(-\lambda r_i)Q_i$$

and we can collect all the terms and simplify the model as

$$P_i = \frac{r_i^{-1}\exp(-\lambda r_i)}{\sum_i r_i^{-1}\exp(-\lambda r_i)} = \frac{Q_i\exp(-\lambda r_i)}{\sum_i Q_i\exp(-\lambda r_i)}$$

Now we have shown that the model uses in this case a constraint on distance travelled plus a prior based on inverse distance to – to produce the model – this in fact is like gamma distribution.

And who looked at this when all of us began work in the area in 1967-8 – but Lionel March

So We Began Our Joint Work in 1974: My Second Theme

Land Use and Built Form Studies
Working Paper No. 24
University of Cambridge School of Architecture
16 Brooklands Avenue, Cambridge

Urban systems: a generalised distribution function

The frequency distribution function which is introduced in this paper is not derived from theoretical considerations, but from a desire to establish a consistent and general pattern for functions which are already employed, or might be used, in describing a wide range of urban-geographic observations. I believe that many situations which have formerly required the use of ad hoc distributions may now be encompassed within the range and flexibility of these functions. Later I shall show that they may be seen to have an interesting and intuitively sound phenomenological basis. My hope, in proposing the use of such a set for fitting empirical data in many areas of urban-geographic studies where physical distance is the principal metric, is that, through consistency of presentation, regularities in spatial organisation will become more apparent and hence more suggestive for the development of an appropriate theory.

In its most general form, the generalised distribution function to be discussed has three parameters, a, b, c, and can be written

$$m(x;a,b,c) = \begin{cases} \dfrac{bc^{a/b}}{\Gamma(a/b)} x^{a-1} \exp(-cx^b), & x > 0 \\ 0 & x \leqslant 0, \end{cases} \tag{11}$$

where $a, b, c > 0$. Clearly $m(x) \geqslant 0$ and, if we let $u = x^b$, it can be easily shown that $\int_{-\infty}^{\infty} m(x)dx = 1$ since the substitution transforms $m(x)$ to a simple gamma distribution in u. Hence $m(x)$ is a probability distribution function.

5

Lionel March

1969

This is Working Paper 24 of the centre for Land Use and Built Form Studies in the University of Cambridge, prepared for presentation at the meeting of the British Section of the Regional Science Association, London, 21–23 August 1969.

August 1969
Second edition July 1971

$$m(x;a,b,c) = \begin{cases} \dfrac{bc^{a/b}}{\Gamma(a/b)} x^{a-1} \exp(-cx^b), & x > 0 \\ 0 & x \leqslant 0, \end{cases}$$

Now when we joined each other at Waterloo, I had been working with ideas about information and I had worked on a measure called *Spatial Entropy* which can be seen as an information difference. I won't go into this here but in 1973 another paper by Hobson and Cheng appeared about information differences. Here is a letter I wrote to the journal back in 1973/4 before I went to Waterloo

Journal of Statistical Physics, Vol. 11, No. 6, 1974

1974

Letter to the Editor

A Comment on the Paper "A Comparison of the Shannon and Kullback Information Measures"[1]

Michael Batty[2]

Received August 7, 1974

The article by Hobson and Cheng, in which they derive Shannon's measure for uncertainty from Kullback's "information for discrimination" statistic demonstrates that the field of information theory is rich in different interpretations. In this spirit, readers may be interested in a related but somewhat oblique comparison between the Shannon and Kullback formulas. First, consider Shannon's formula for continuous entropy $S(x)$

$$S(x) = -\int \rho(x) \ln \rho(x)\, dx \tag{1}$$

[1] The paper "A Comparison of the Shannon and Kullback Information Measures" by Arthur Hobson and Bin-Kang Cheng appeared in *J. Stat. Phys.* 7(4):301 (1973).

[2] Department of Geography, University of Reading, Whiteknights, Reading, England.

Environment and Planning B, 1975, volume 2, pages 99–105

Generalized measures of information, Bayes' likelihood ratio and Jaynes' formalism

L March
Department of Systems Design, University of Waterloo, Ontario, N2L 3GI, Canada
M Batty ¶
Department of Civil Engineering, University of Waterloo, Ontario, N2L 3GI, Canada
Received 4 July 1975

Abstract. This paper relates generalized measures of information to expected likelihood functions (ELFs) derived from Bayes' equation. It then demonstrates that Jaynes' formalism may be extended to formulate a *class* of minimally-prejudiced models of which those derived from Shannon's measure are but a limiting and special case. The rôle of probable inference and of information-minimizing models in design is commented on.

- Our first paper articulated the idea of Bayes theorem and information minimising, drawing on Aczel's ideas – Aczel was at Waterloo too in the same department as Bill Tutte: *Combinatorics and Optimisation*

Lionel knew all about this somehow: the paper by Jaynes on prior probabilities was important then and also Lionel went to see Myron Tribus who was at Xerox In Rochester NY, not so far away.

We then decided to look at what a good prior was and Lionel introduced me to James S. Coleman’s method of residues – based on the idea that you filter out what is obvious and then what is left – the residues are to be explained.

In Coleman’s book (1964), he shows this for the notion of geometric space that gets exponentially larger as you travel away from an origin, hence making the probability of travelling to those further spaces intrinsically decreasing.

We both knew about the book but it was Lionel who knew about the method. I then applied it to a gravity model formulation in the Toronto region. I did buy the book in fact when I returned to UK in 1975 and it still floats around CASA

INTRODUCTION TO MATHEMATICAL SOCIOLOGY

JAMES S. COLEMAN
Johns Hopkins University

The Free Press, New York

CHAPTER 15

THE METHOD OF RESIDUES

The example of natural science has led social scientists to treat postulate systems in a very narrow and restricted way. Because in mechanics a law holds or does not hold, a theory is confirmed or denied, many of us have set about finding and explaining the "true" regularities and uniformities of behavior, holding this aim to be the one proper object of our science. Perhaps this may be, in the long run, the one primary goal to which we should aspire—or perhaps not. But for the present, to limit our goals to those of proposing and confirming explanatory postulate systems may lead us to overlook valuable aids to research and theory.

One such aid is of this sort: in considering a given complex social phenomenon, certain aspects of it are explainable by "sociologically trivial" assumptions, or by matters irrelevant to the substantive matters under investigation. If we examine what part of the behavior can be explained by these "trivial" factors, then the remainder stands out to be explained by less trivial factors. Ordinarily such separating out of the sociologically trivial elements must be done qualitatively and nonrigorously. But in certain structural phenomena, where the data are in the form of numbers of people,

469

Environment and Planning A, 1976, volume 8, pages 189-214

The method of residues in urban modelling

M Batty
Department of Geography, University of Reading, Whiteknights, Reading, RG6 2AF, Berkshire, England
L March
Department of Design Technology, The Open University, Walton Hall, Milton Keynes, MK7 6AA, England
Received 11 July 1975

Abstract. This paper seeks to extend the macrostatic approach to urban modelling by treating modelling problems as many-stage processes. Within such a process the early stages are concerned with explaining the relatively trivial characteristics of the phenomena of interest, and the later stages are devoted to explaining more important behavioural issues. Coleman (1964) calls this approach the 'method of residues', and its power is first demonstrated here by a reinterpretation of the well-known gravity model. An ad hoc test of the method on the Toronto-centred region serves to emphasise the need for a more formal approach, and thus an analogy between the method and the Bayesian viewpoint is introduced. A method of information minimising, more general but consistently and unambiguously related to the method of entropy maximising, is used to make the formal approach operational, and the method is used to generate an 'extended' family of spatial-interaction models. A number of spatial-interaction models are derived, and the paper is concluded by a test of two of these models on the Toronto-centred region.

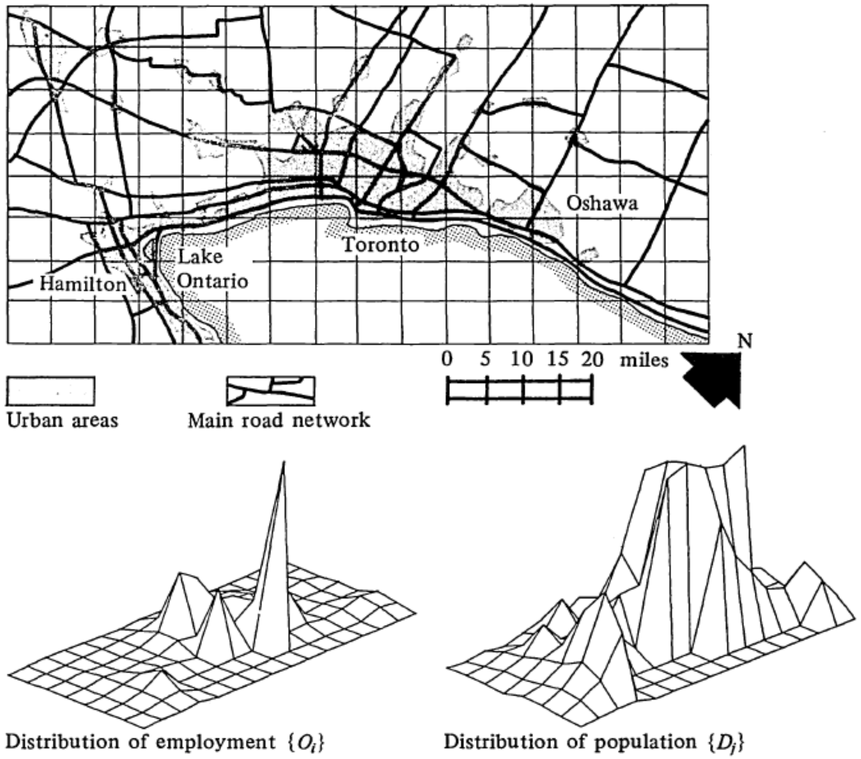


Figure 1. Spatial form of the Toronto-centred region.

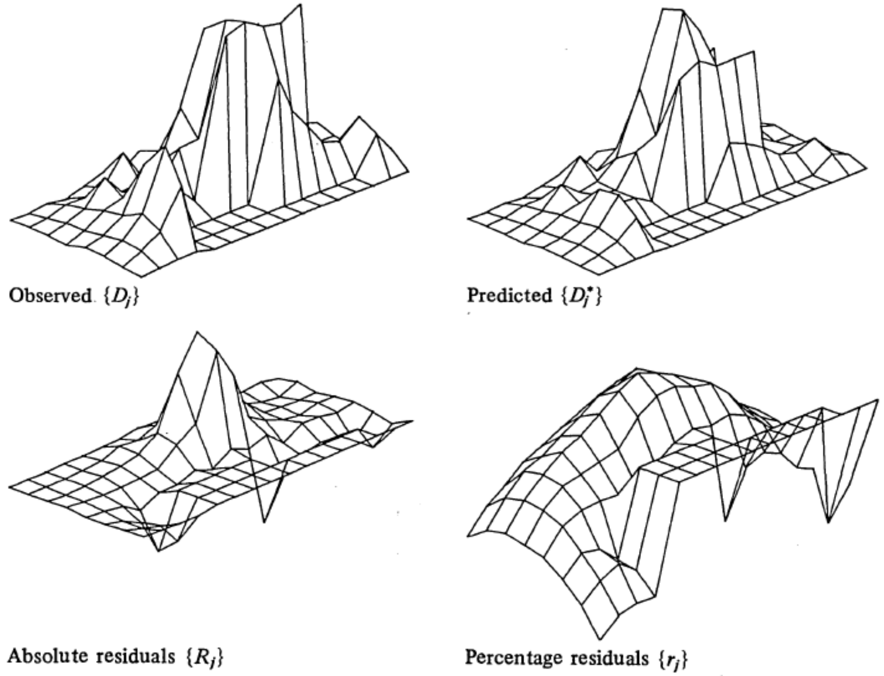


Figure 3. Spatial predictions and residuals from the Coleman–Zipf model.

Waterloo was a truly remarkable place – they gave you money for doing research and engineering gave us money to run a two day colloquium on all this in July 1975

COLLOQUIUM ON SOCIO-ECONOMIC SYSTEMS DESIGN IN URBAN AND REGIONAL PLANNING

A RESEARCH SEMINAR HELD ON JULY 28 - 29, 1975, IN THE UNIVERSITY OF WATERLOO, WATERLOO, ONTARIO, CANADA.

ORGANISERS

Michael Batty, Department of Civil Engineering, University of Waterloo, and Department of Geography, University of Reading.

Lionel March, Department of Systems Design, University of Waterloo, and Department of Architecture, University of Cambridge.

University of Waterloo

Waterloo, Ontario, Canada
N2L 3G1

Faculty of Engineering
Department of Civil Engineering
519/885-1211

FINAL PROGRAMME

COLLOQUIUM ON SOCIO-ECONOMIC SYSTEMS DESIGN
IN URBAN AND REGIONAL PLANNING: 28-29 JULY, 1975

in

ARTS LECTURE HALL, ROOM 105

MONDAY, 28th JULY, 1975:

9-30 a.m. Coffee

10-00 a.m. Lionel March, Department of Systems Design, University of Waterloo, and Department of Architecture, University of Cambridge: Introduction to the Seminar

10-30 a.m. Marcial Echenique, Director, the Martin Centre for Urban and Architectural Studies, University of Cambridge: Experiences with Urban Models in Britain and South America

11-30 a.m. Bruce Hutchinson, Department of Civil Engineering, University of Waterloo, and A.C. Sarna, Central Road Research Laboratory, Delhi, India: A Land-Use Transport Model for Delhi, India

12-30 p.m. - 2-00 p.m. LUNCH

2-00 p.m. DISCUSSION GROUPS

(i) (i) in Room 105: Land Use Models in Developing Countries, Discussion to be lead by Bruce Hutchinson

(ii) in Room 212: The Role of Model-Building in the Planning Process, Discussion to be lead by Michael Batty

(iii) in Room 213: The Theory of Design and Model-Building in Social and Economic Systems, Dicussions to be lead by Lionel March.

3-15 p.m. Coffee

3-45 p.m. Alberto Feo, Instituto de Urbanismo, Faculty of Architecture, Central University of Venezuela, Caracas: The CARACAS Models: Problems, Performance and Planning Applications

4-45 p.m. Michael Batty, Department of Civil Engineering, University of Waterloo, and Department of Geography, University of Reading: Summary of the First Day's Proceedings

- 2 -

TUESDAY, 29th JULY, 1975

10-00 a.m. Henk Edens, Department of Civil Engineering, University of Waterloo: Conceptual Development of a Residential Land Use Model

11-00 a.m. Coffee

11-30 a.m. Michael Batty: The Method of Residues in Urban Modelling

12-30 p.m. - 2-00 p.m. LUNCH

2-00 p.m. DISCUSSION GROUPS

(i) in Room 105: Theoretical Methods for the Design of Urban Models, Discussion to be lead by Alberto Feo, and Lionel March

(ii) in Room 212: Practical and organisational Considerations in Developing Models in Rapidly Changing Environments, Discussion to be lead by Marcial Echenique and Bruce Hutchinson

3-15 p.m. Coffee

3-45 p.m. Lionel March: Speculations on a New Approach to Socio-Economic System Design through Information Theory

4-45 p.m. Bruch Hutchinson et al: Summary of the Seminar and Conclusions

---

This colloquium has been made possible by the Research Grants Committee, the Faculty of Engineering, the Transport Group (Civil Engineering) and the Department of Systems Design, University of Waterloo.

I returned to the UK – to the University of Reading where I was a lecturer in Geography – and my wife finished her MASc degree in Systems Design – another pretty unique coincidence as she had applied to do this not knowing that Lionel was going to Waterloo as we were at that time. This was a pretty amazing coincidence which I only found out about at the Land Use Models conference here in Cambridge in July 1974 and we were destined to fly in early August.

My wife in fact wrote a Master's thesis on game-theory in design and Lionel was her advisor. All pretty incestuous and she published a paper on this in EPB in 1977

Anyway we didn't worry about things like that in those days

Environment and Planning B, 1977, volume 4, pages 211-239

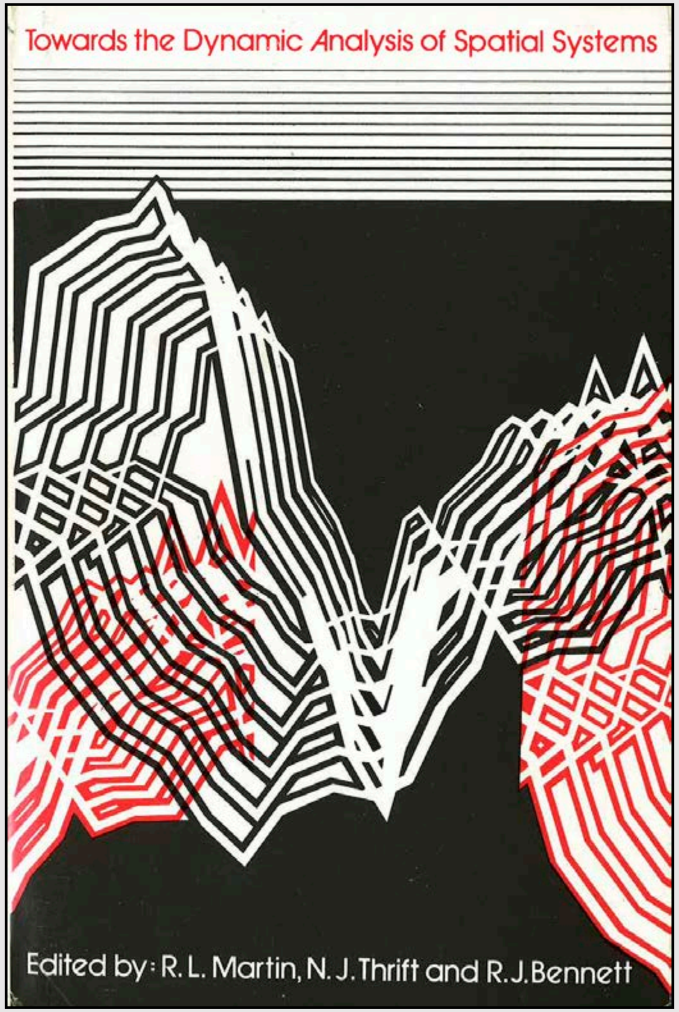
Game-theoretic approaches to urban planning and design

Susan E Batty
Department of Town Planning, Oxford Polytechnic, Oxford OX3 0BP, England
Received 26 January 1976, in revised form 18 August 1977

Abstract. In this paper the urban-planning process is explored and modelled using a variety of concepts and techniques drawn from the theory of games. The rationale for using game theory as a basis for simulating the design process is presented first, and this serves to highlight the major features of such processes in terms of bargaining and the implied power positions of the players involved. In the second section these ideas are given substance through a description of a case study based on the choice of location of a town to accept overspill population from a large conurbation, and a number of conceptual game-theoretic models of parts of this process are presented. By developing game theory nonalgebraically in terms of this case study, it is then possible to generate a set of formal models based on stochastic game theory, as first suggested by Shapley (1953). These models are presented theoretically in the third section, and in terms of their algorithms and application in section four. These models include several different features including a multigame stochastic format in which participants move between game elements according to transition probabilities conditional on their joint decisions, an hierarchical property which enables participants to move between various levels of negotiation, and the use of the nucleolus, a cooperative-game-solution concept first introduced by Schmeidler (1969). An evaluation of the strengths and weaknesses of game theory in this context forms the conclusion.

My last piece of work with Lionel was after I returned. We applied information-minimising to a little model of the Reading region. I remember presenting this in Foster Court where Geography was located in UCL in late 1975, maybe 1976.

And a book came out with our paper with a somewhat amazing array of authors – let me show you


Towards the Dynamic Analysis of Spatial Systems
Edited by: R. L. Martin, N. J. Thrift and R. J. Bennett

Contents

And so to my third and last theme

I am very attracted to the idea of data-driven models and I think that we can go a very long way with this – all our data in fact is lagged in the past and I believe we could well make a lot of progress in using that data directly as it contains all the information which is encoded about how the urban system works – in other words we make our models ever better by continually updating them – priors into posteriors and so on and we start with the data.

I had a go at this about 3 years ago and never completed it. I will have another go in the next half year or so and will present a paper next November at the NARSA meeting in San Antonio, TX, I hope.

Let me end with a nice picture of

Lionel

from Peter Carolin via Phil Steadman