

Fractal approaches to combat modelling

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Drivers

- Lack of models available. Simple “Lanchester” approaches the principal option
- Had a broad range of problems, including issues such as Recce and C2
- Agent-based models seemed like a good approach but not “Physics based”

Origins of our approach

- The physics of weather: more detail does not give better answers
- Simple fractal models seem to better reproduce statistics of weather than supercomputers
- Differential equations do not seem to be able to describe complex systems
- Self-organisation important

Hypothesis

- Assume combat is a self-organising system
- Further assume combat data can be characterised in terms of fractal dimensions
- Then, fractal dimension of combat data can be related to the attrition function

Blue attrition

Function of:

- Number of Red
- Time
- Kill probabilities
- Fractal dimension of distribution

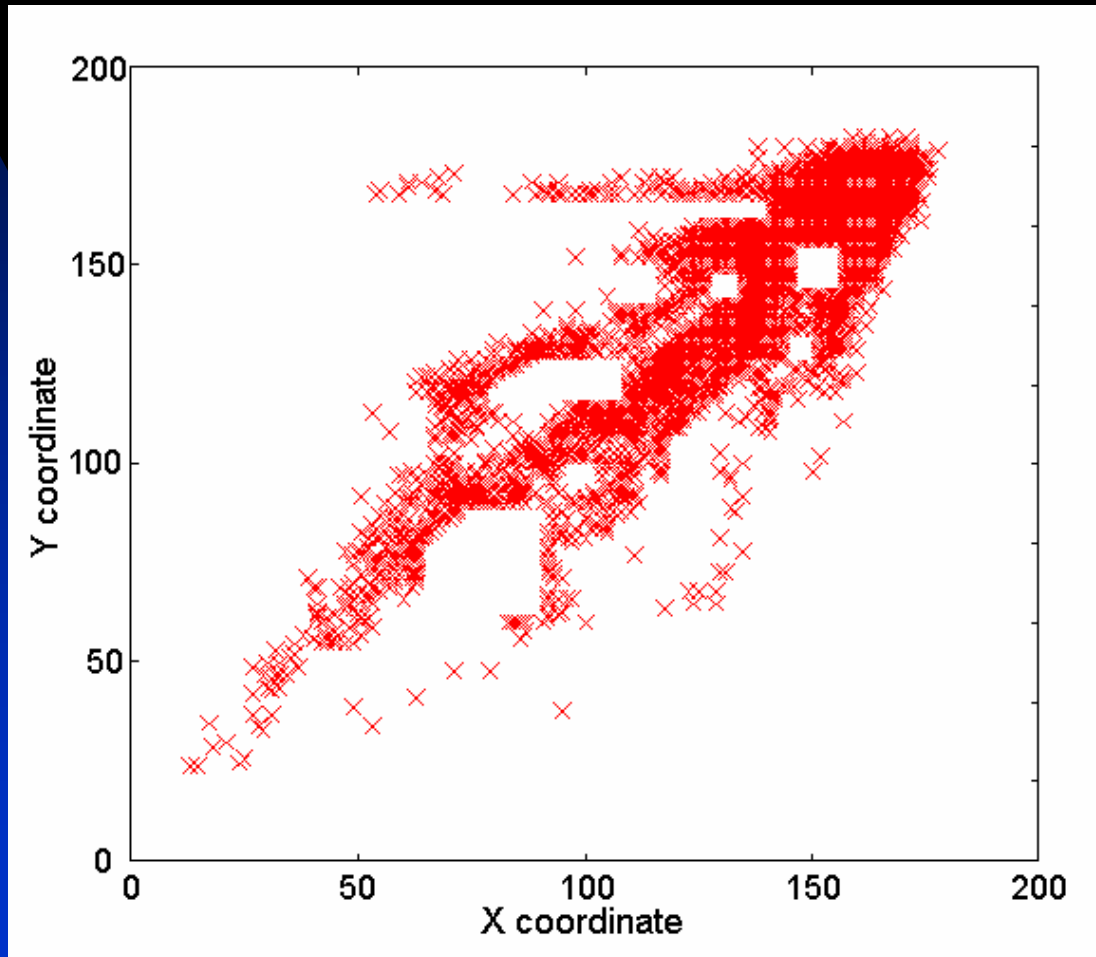
$$\frac{\Delta B}{\Delta t} = f(R, t, k_r, D)$$

A convenient form is:

$$\left\langle \frac{\Delta B}{\Delta t} \right\rangle \propto R k_r^{E(D)} \Delta t^{-F(D)}, \quad E + F = 1$$

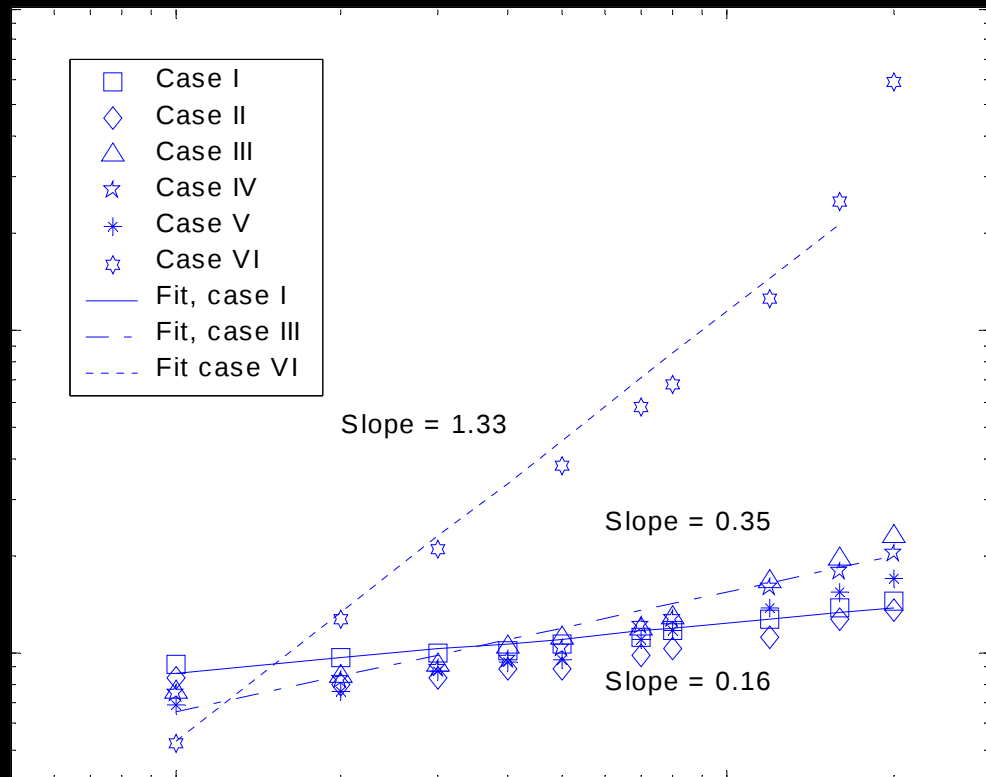
- Two parts: k and t
- Ensemble of runs with similar distribution of Red.
- Can choose by requiring a minimum casualty level.
- Reduces to the Lanchester equation.

Fractal pattern (MOUT)



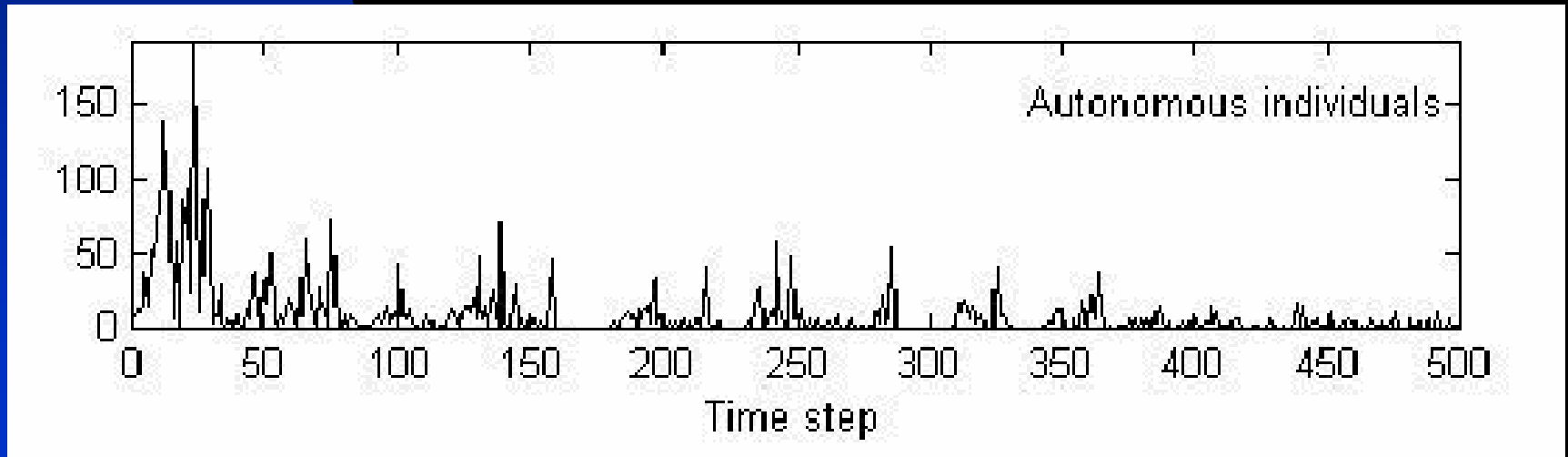
The k part:

- Different patterns for different behaviours, implies differing attrition rates.

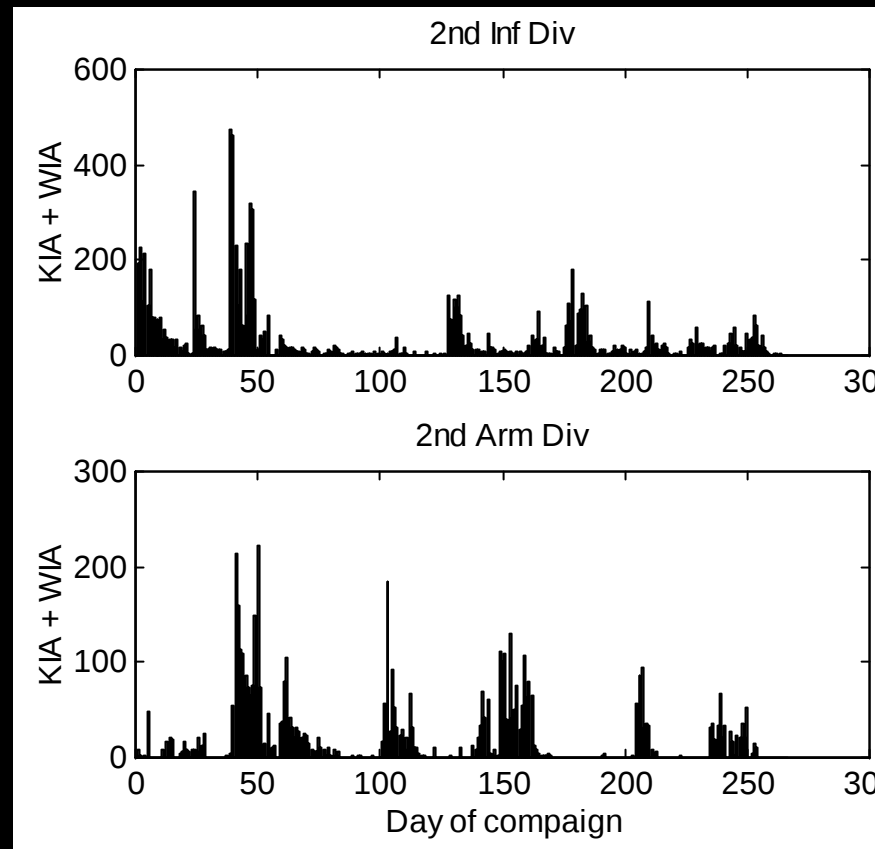


The t part:

- Implies that the attrition function itself should have a specific temporal structure.
- Should be intermittent and clustered
i.e. when it rains it pours.



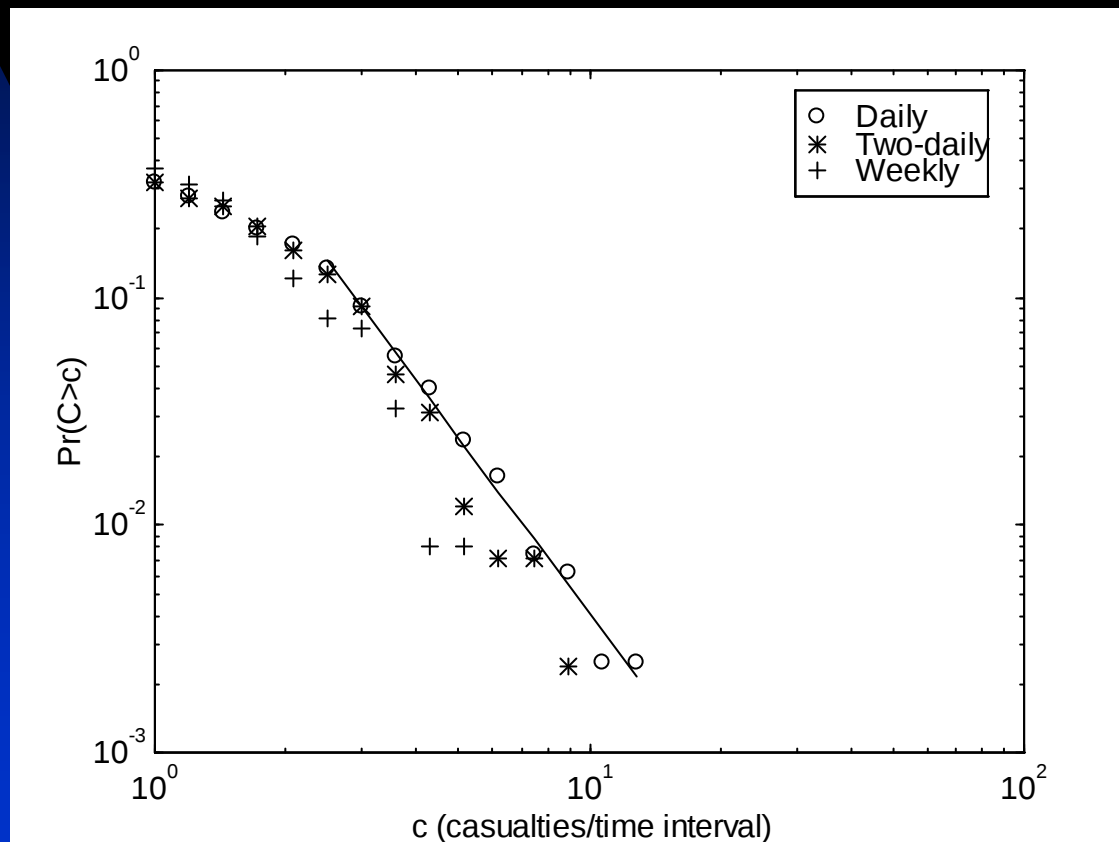
Historical data confirms our hypothesis!



Applications

Has implications for C2 and logistic loads etc.

$$C = \left(\frac{P}{1.68} \right)^{-0.4}$$



Casualty estimation

Percentile	Normalized estimate	Actual 1 st Inf Div estimate (actual)	Actual 2 nd Inf Div estimate (actual)	Actual 4 th Inf Div estimate (actual)	Actual 2 nd Arm Div estimate (actual)
90%	3.1	98 (92)	110 (88)	206 (186)	61 (64)
95%	4.1	130 (100)	145 (130)	271 (253)	81 (95)
99%	7.8	248 (159)	278 (319)	517 (470)	154 (160)
Mean	1.0	31.8	35.6	66.4	19.8

Understanding historical results

$$C = (\text{Number of attackers} / \text{Number of defenders})^{0.685}$$

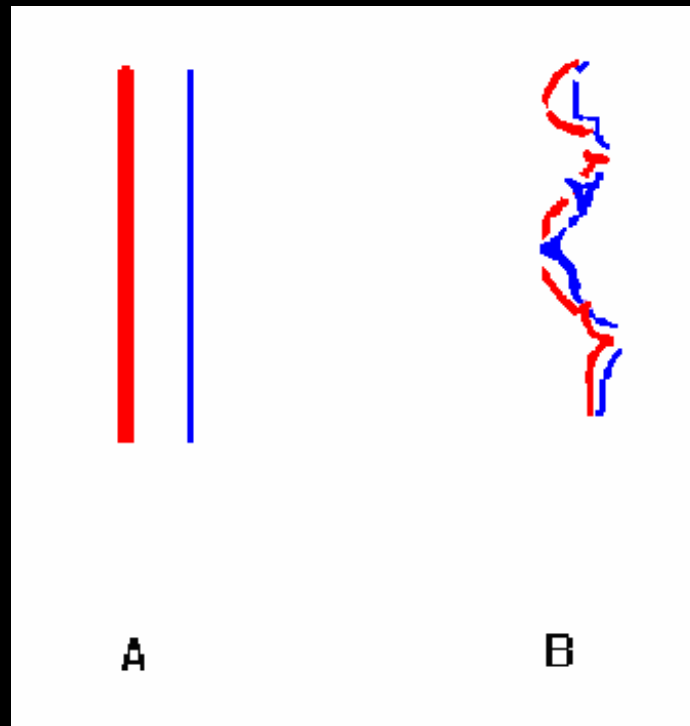
- Thornton (UK)
- Osipov (Russia)
- Helmbold (US)

Inconsistent with Lanchester!

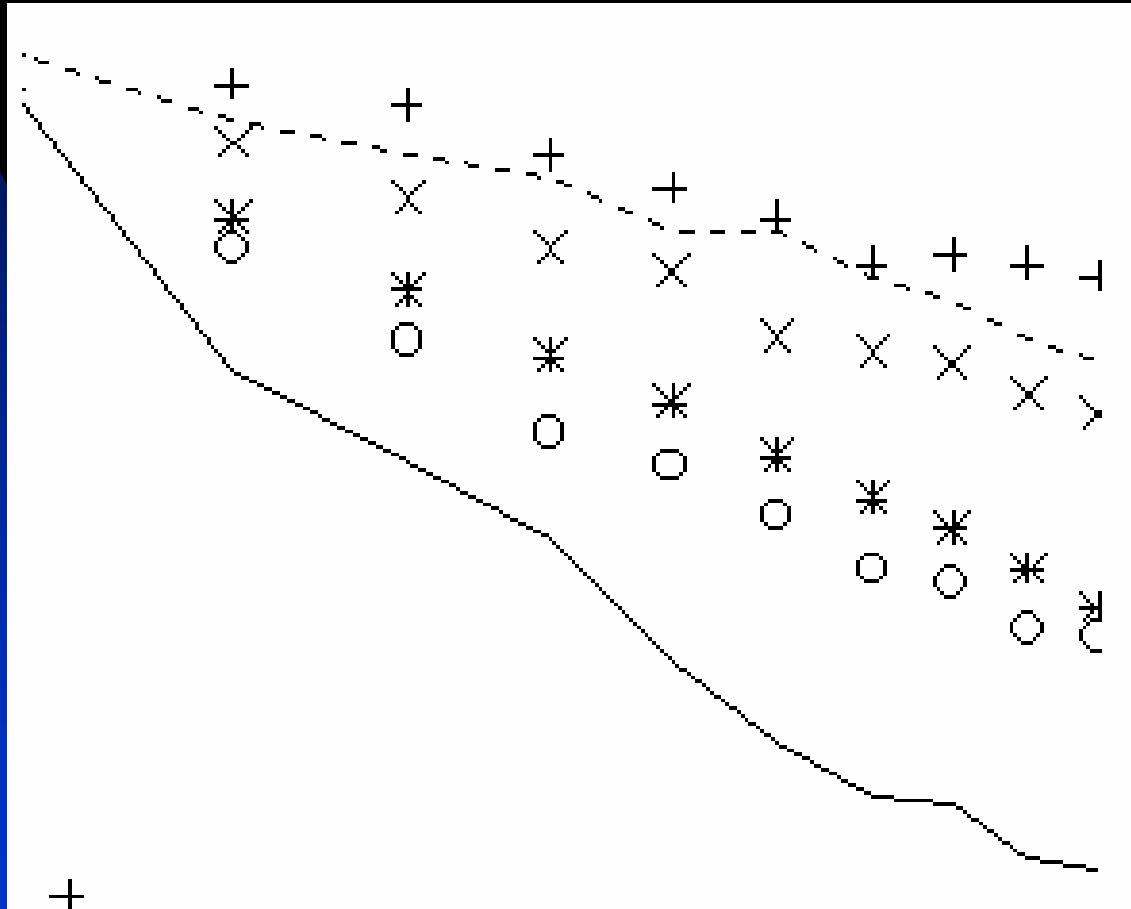
Fractal idea

- Check with agent-based models
- Behaviour (tactics) causes battles to evolve in similar (but not exactly the same) ways
- Could there be a fractal attractor at work?

- Battles evolve into an attractor with the same fractal dimension for the same types of battles (related to ideas proposed by Jim Moffat)



Find values for D :



What this gives us

- Fractal nature of combat data tells us our models need to produce output consistent with fractals
- Thus, fractals provide a method by which we can judge if the complexity is being characterised properly by our models
- Can characterise sophisticated differences in forces by a single parameter!