







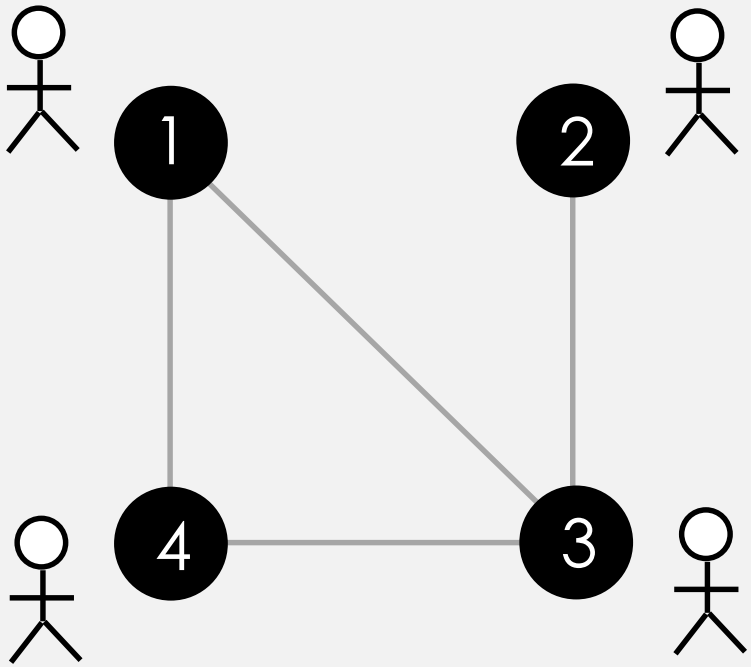


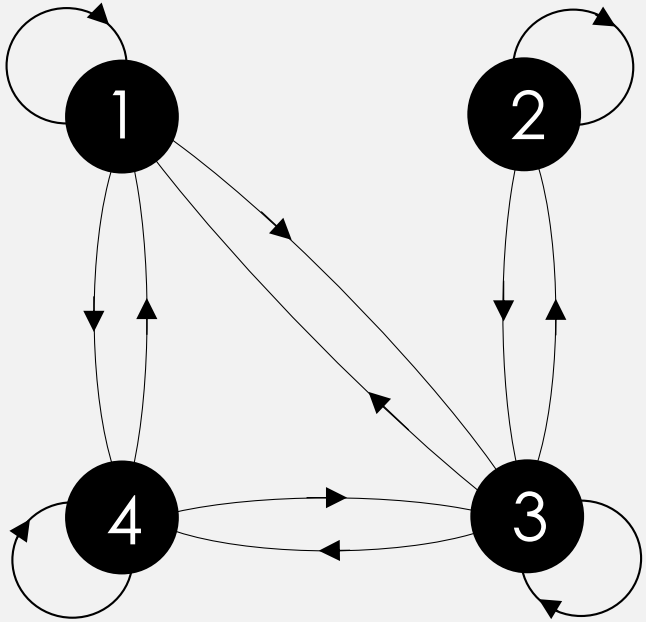
Planning as Conflict Resolution:

Opinion Pooling Across Networks to Generate Physical Plan Designs

Michael Batty
Centre for Advanced Spatial Analysis
CASA-UCL

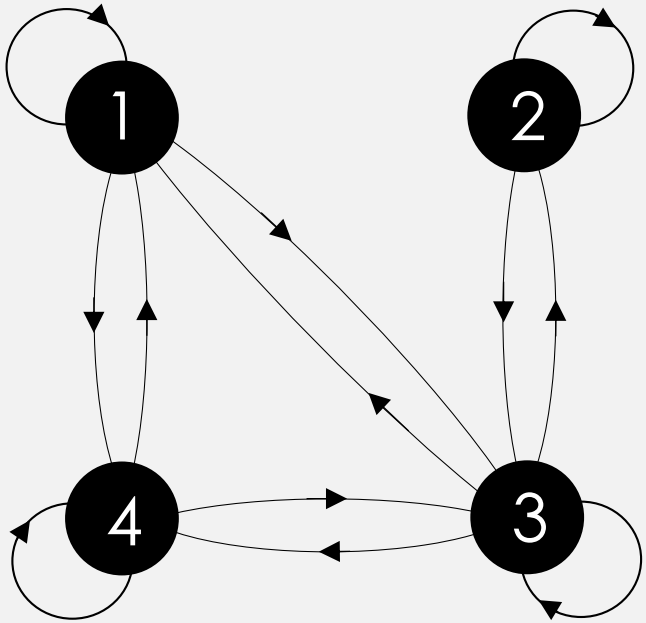
m.batty@ucl.ac.uk
@jmichaelbatty

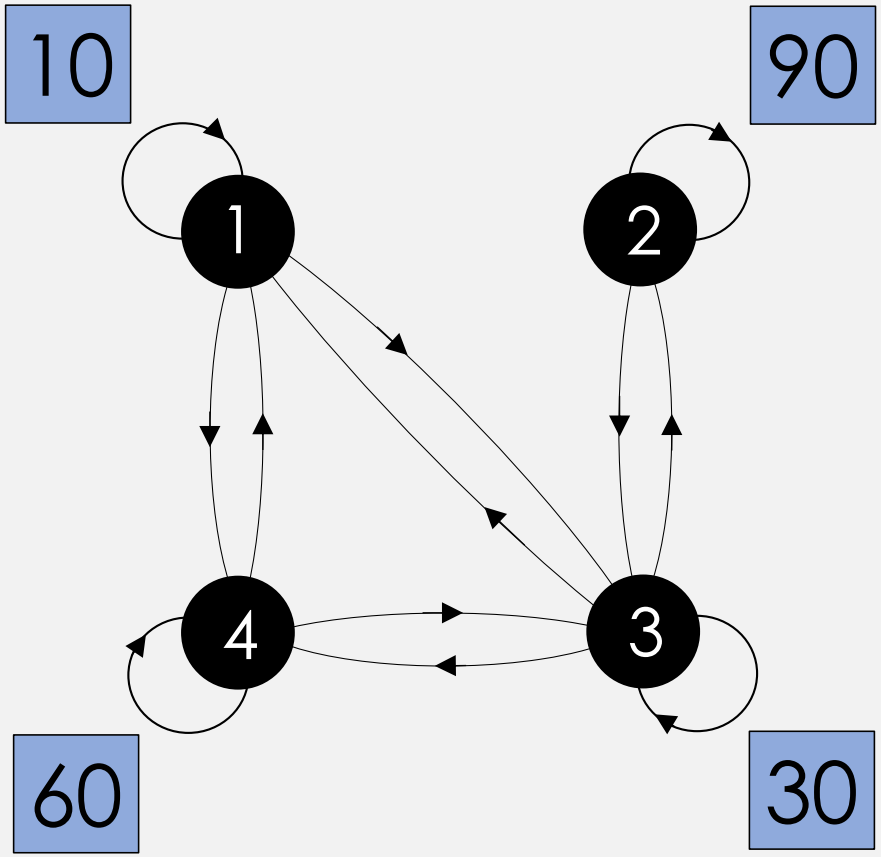

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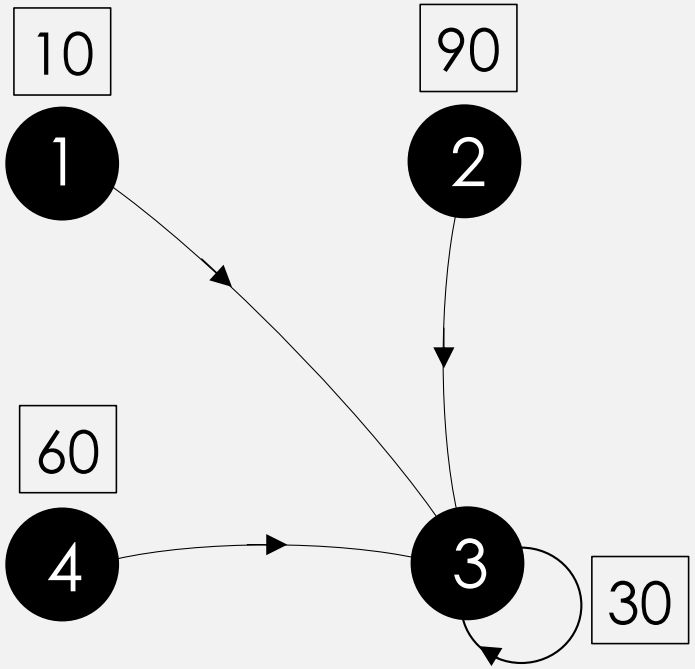
So this is our communications network where we can swap ideas – to some purpose such as pooling our opinions

Let us see how it works on a simple problem





We will give each actor in the network an opinion – here ***a number*** and then operate the network by asking them to communicate this number to their nearest neighbours – and then form ***a compromise*** – which is ***an average*** – a ***weighted*** average



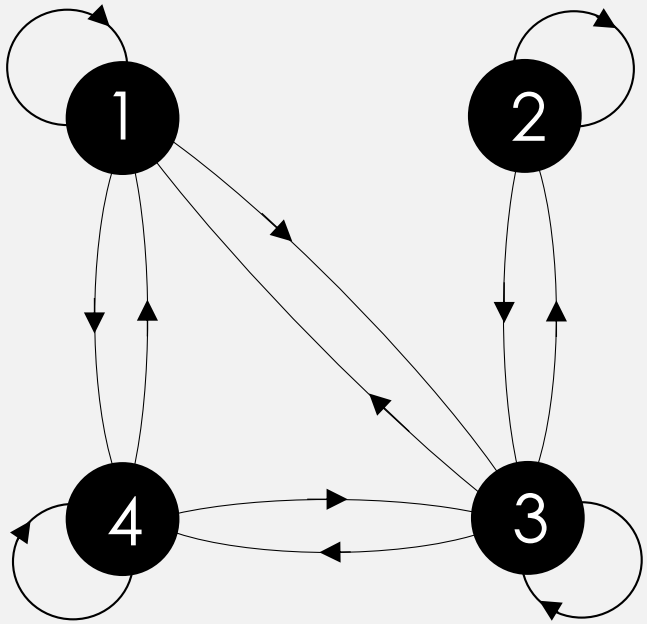
This is how it works – we will illustrate it for actor 3 actor 1 communicates with 3 first then actor 2 then actor 4 does: and actor 3 then forms an 'average' of these 3 opinions with its own

(10 + 90 + 30 + 60) / 4 =
190/4 =.....47.5

(10+60+30)/3

= 100/3

= 33.33



(90+30)/2

= 120/2

= 60

(10+60+30)/3

= 100/3

= 33.33

10+90+30+60)/4

= 190/4

= 47.5

Now let us see what happens when we continue this process – already after the first pass, the weighted averaging reduces the difference between the numbers. If we continue this we get …

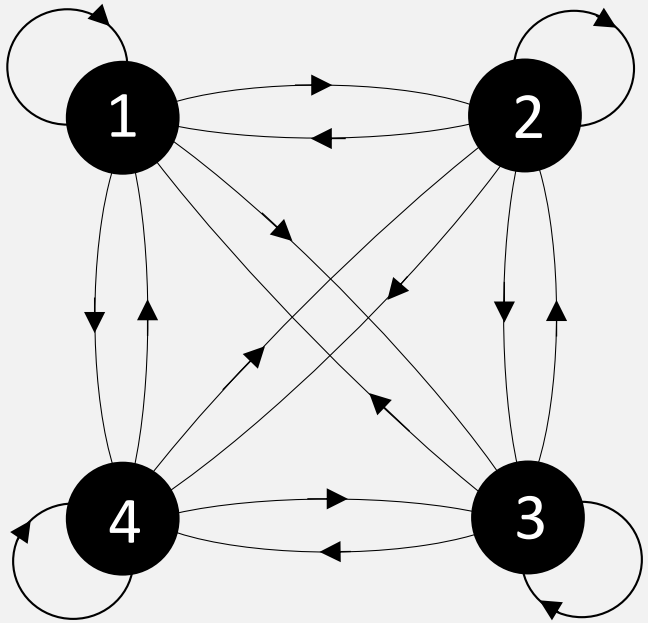
	Actor 1	Actor 2	Actor 3	Actor 4	
No of Actor	1.00	2.00	3.00	4.00	
Value-Number	10.00	90.00	60.00	30.00	
Digital	33.33	60.00	33.33	47.50	
2.00	38.06	53.75	38.06	43.54	
3.00	39.88	48.65	39.88	43.35	
4.00	41.04	46.00	41.04	42.94	
5.00	41.67	44.47	41.67	42.75	
6.00	42.03	43.61	42.03	42.64	
7.00	42.24	43.13	42.24	42.58	
8.00	42.35	42.85	42.35	42.55	
9.00	42.42	42.70	42.42	42.53	
10.00	42.45	42.61	42.45	42.51	

Let us see how it works on a simple problem

	Actor 1	Actor 2	Actor 3	Actor 4
No of Actor	**1.00**	**2.00**	**3.00**	**4.00**
Value-Number	**10.00**	**90.00**	**60.00**	**30.00**
1.00	33.33	60.00	33.33	47.50
2.00	38.06	53.75	38.06	43.54
3.00	39.88	48.65	39.88	43.35
4.00	41.04	46.00	41.04	42.94
5.00	41.67	44.47	41.67	42.75
6.00	42.03	43.61	42.03	42.64
7.00	42.24	43.13	42.24	42.58
8.00	42.35	42.85	42.35	42.55
9.00	42.42	42.70	42.42	42.53
10.00	**42.45**	**42.61**	**42.45**	**42.51**

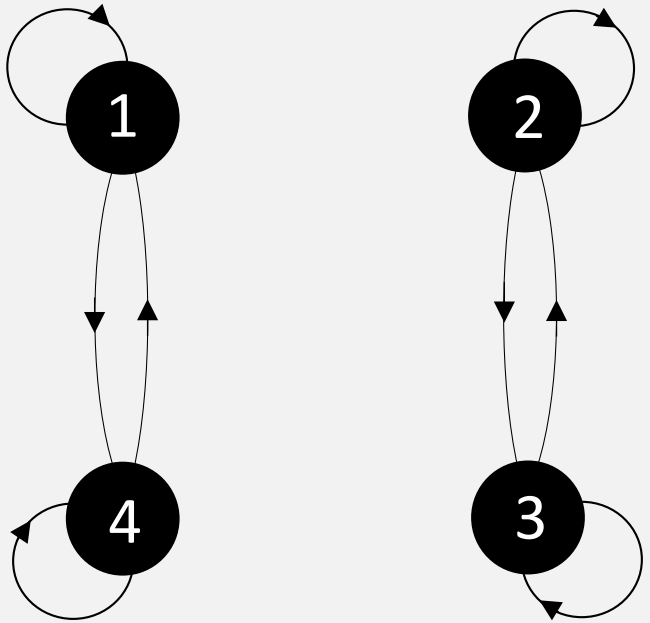
In fact if we have a network where everything is connected to everything else, we get immediate consensus – a network like this

If we have one that is disconnected we don't get convergence or consensus



In fact if we have a network where everything is connected to everything else, we get immediate consensus – a network like this

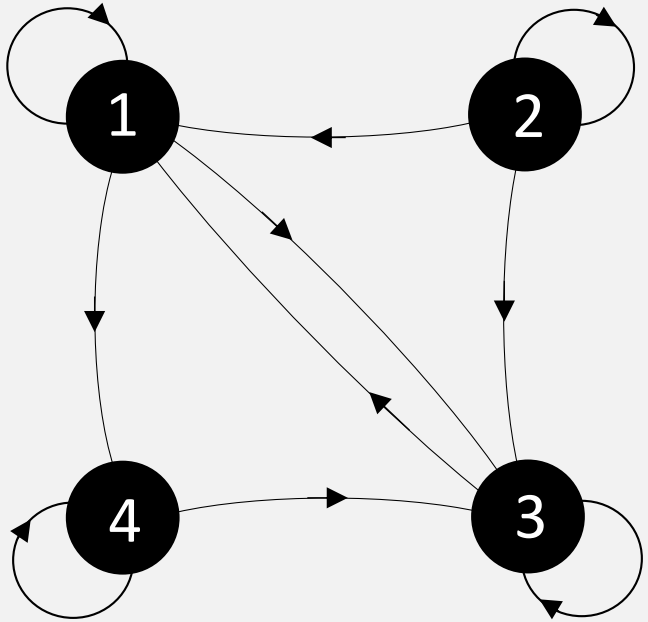
If we have one that is disconnected we don't get convergence or consensus

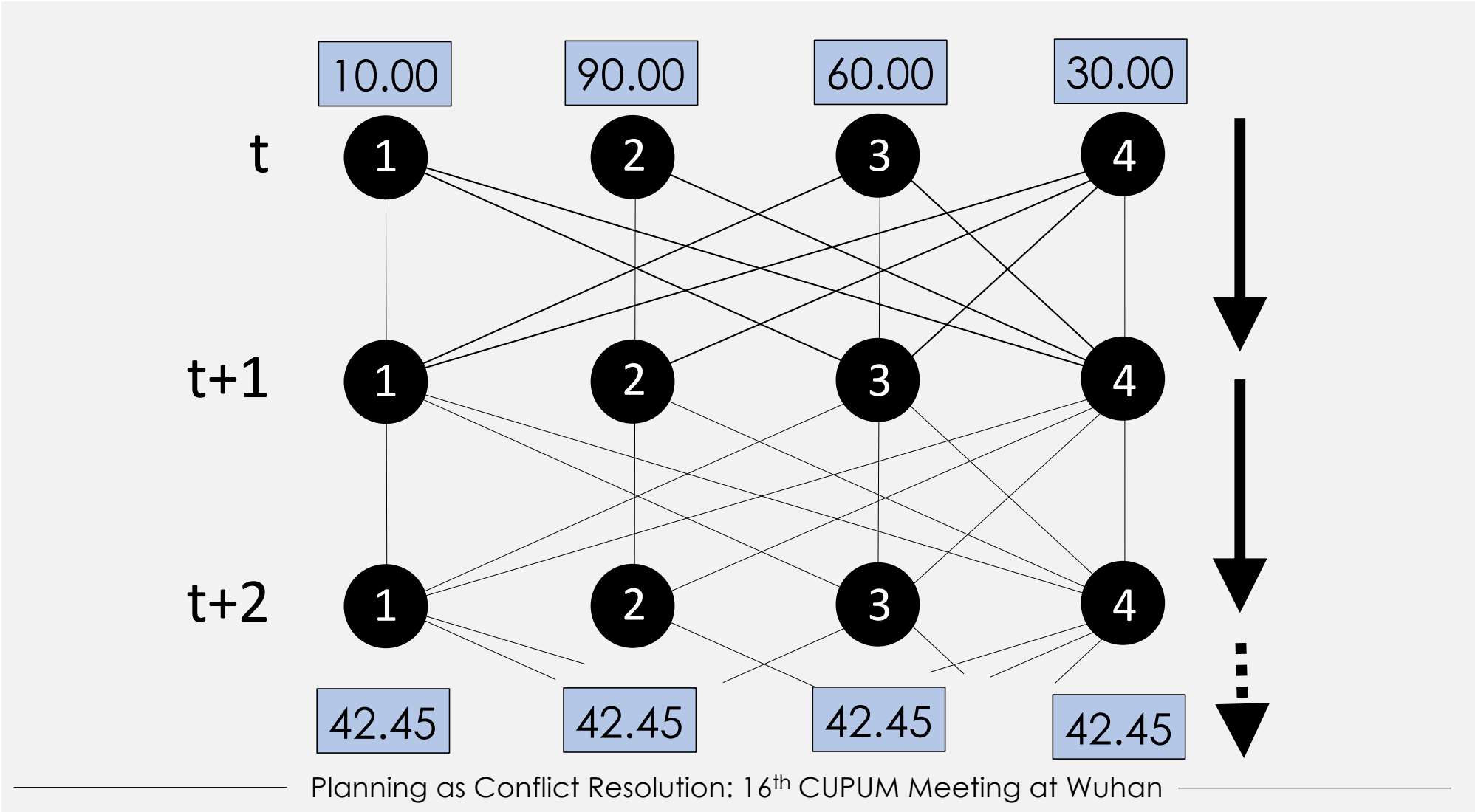


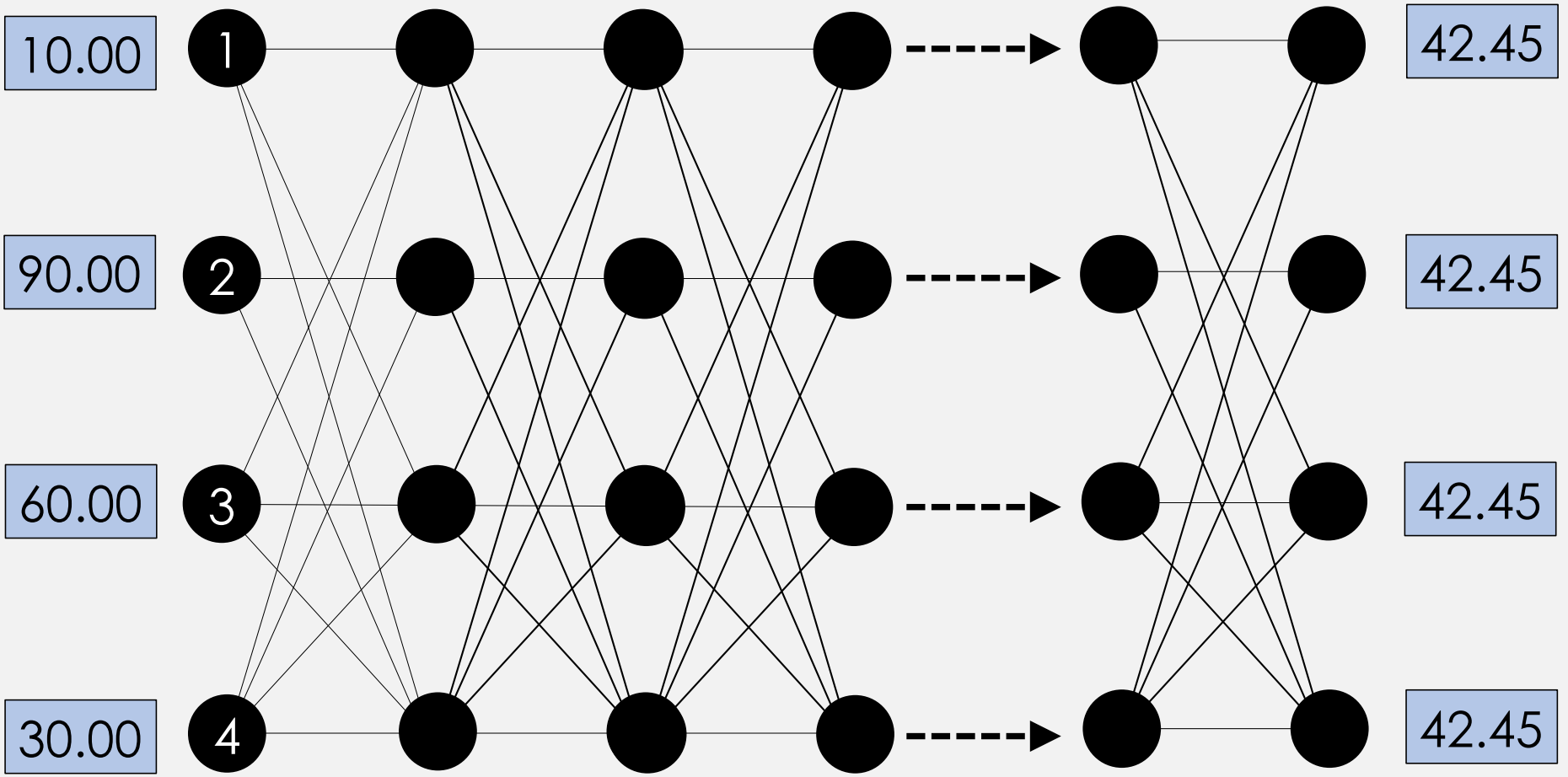
And we can have networks that imply that one actor dominates the final solution and so on and soon

We can have differential weights on the links as well as different topologies

Here actor 2 will dominate and the solution will be 90




10.00
90.00
60.00
30.00
t
t+1
t+2
1
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42.45
42.45
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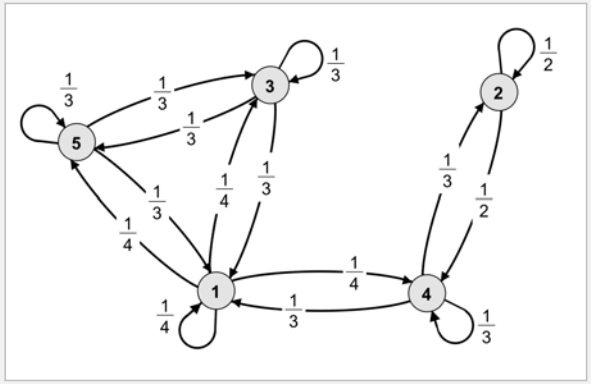

10.00
90.00
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42.45
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42.45

So what does this remind you of

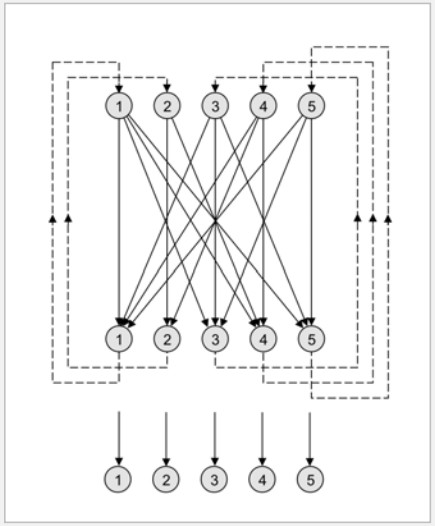
Yes, Neural Nets, the darling of machine learning !....

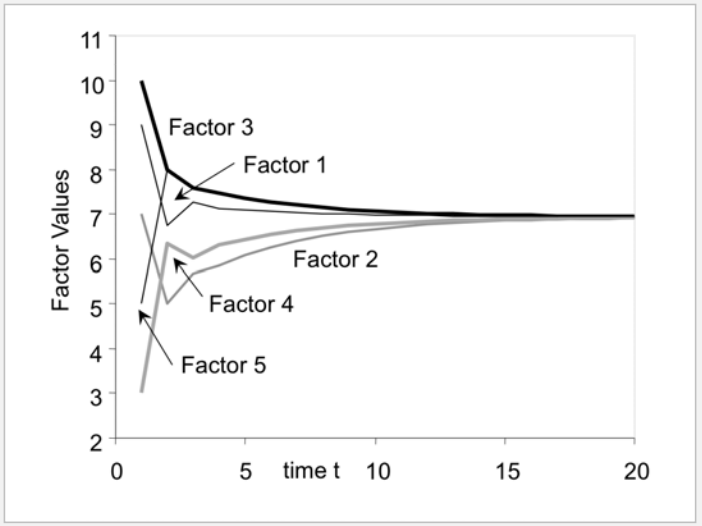
Here we are not bombarding our senses with images so that we can extract patterns for recognition but we are converging on a solution in the same way. But this doesn't imply learning. It could do if we altered the weights though – the layer is just repeated until convergence

A Summary So Far: The Network, The Averaging Process, the Machine



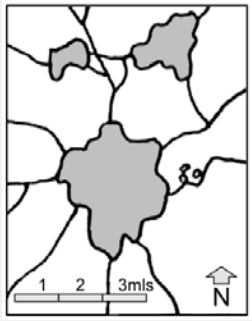
$$\begin{bmatrix} 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} 1/4 & 0 & 1/4 & 1/4 & 1/4 \\ 0 & 1/2 & 0 & 1/2 & 0 \\ 1/3 & 0 & 1/3 & 0 & 1/3 \\ 1/3 & 1/3 & 0 & 1/3 & 0 \\ 1/3 & 0 & 1/3 & 0 & 1/3 \end{bmatrix}$$

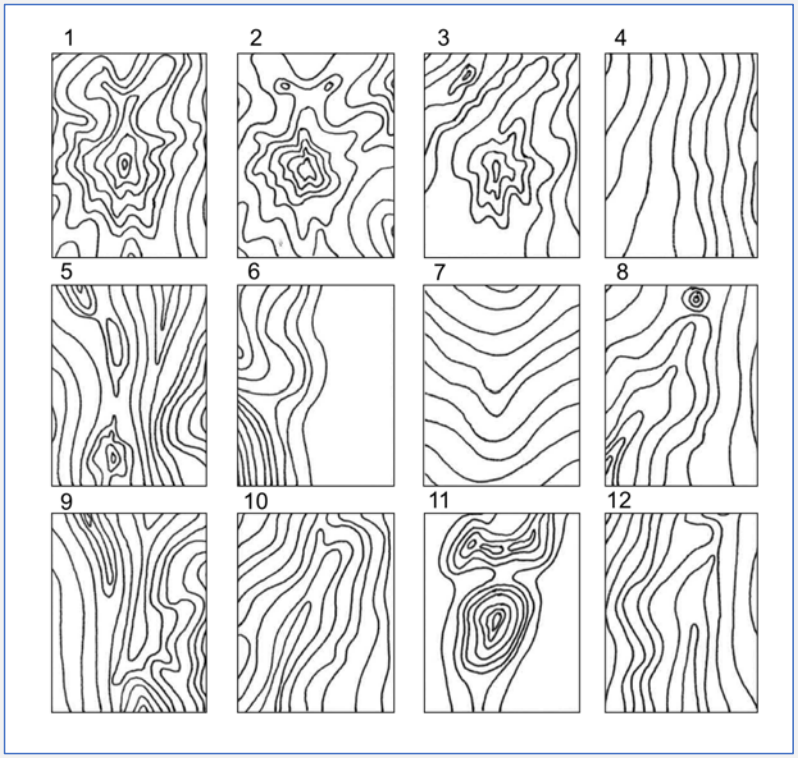


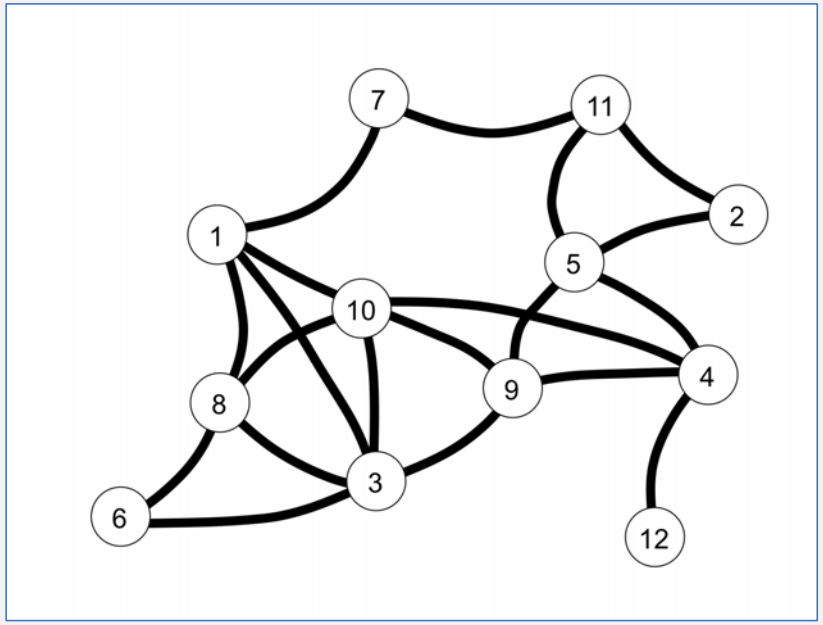


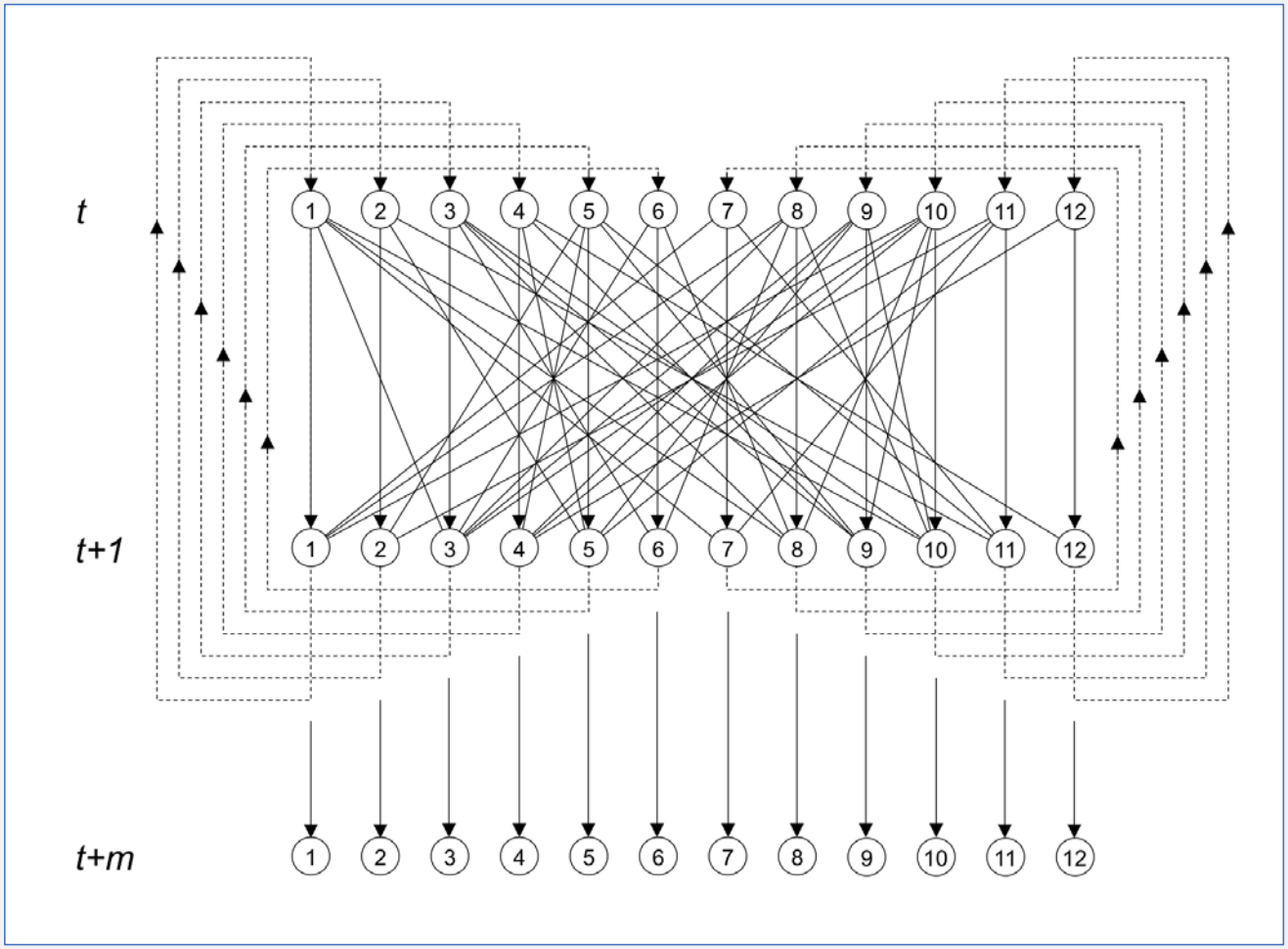
Spatial Averaging: An Example

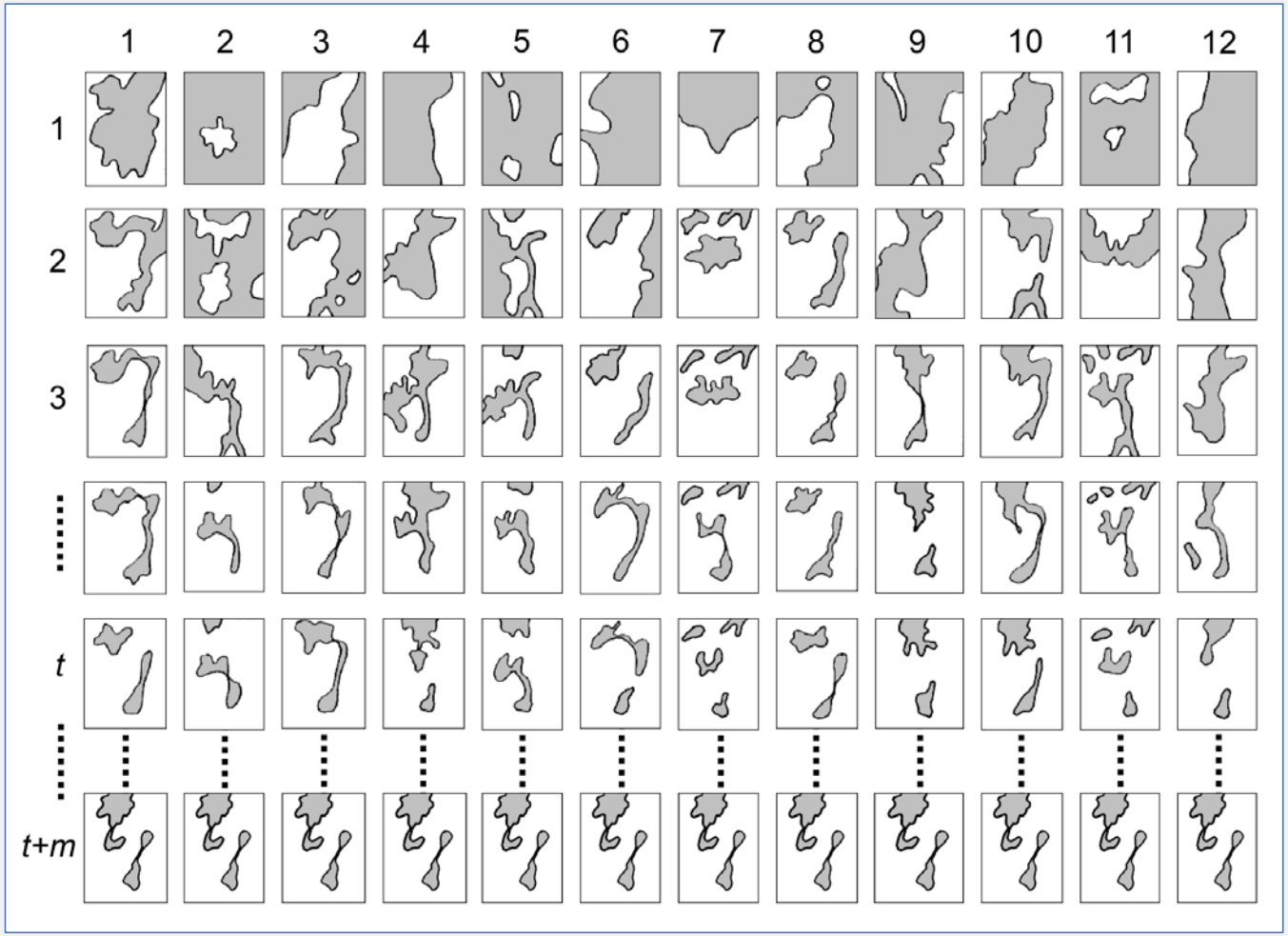
- A set of factors showing the desirability of land development –our opinions expressed as maps
- These conflict with one another
- We form a network showing the strongest conflicts – any measure of similarity/dissimilarity
- We make sure the network is connected as this implies the weights
- We perform the averaging


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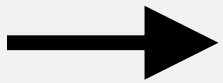

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t+1
t+m
1
2
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11
12


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7
8
9
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12
1
2
3
t
t+m

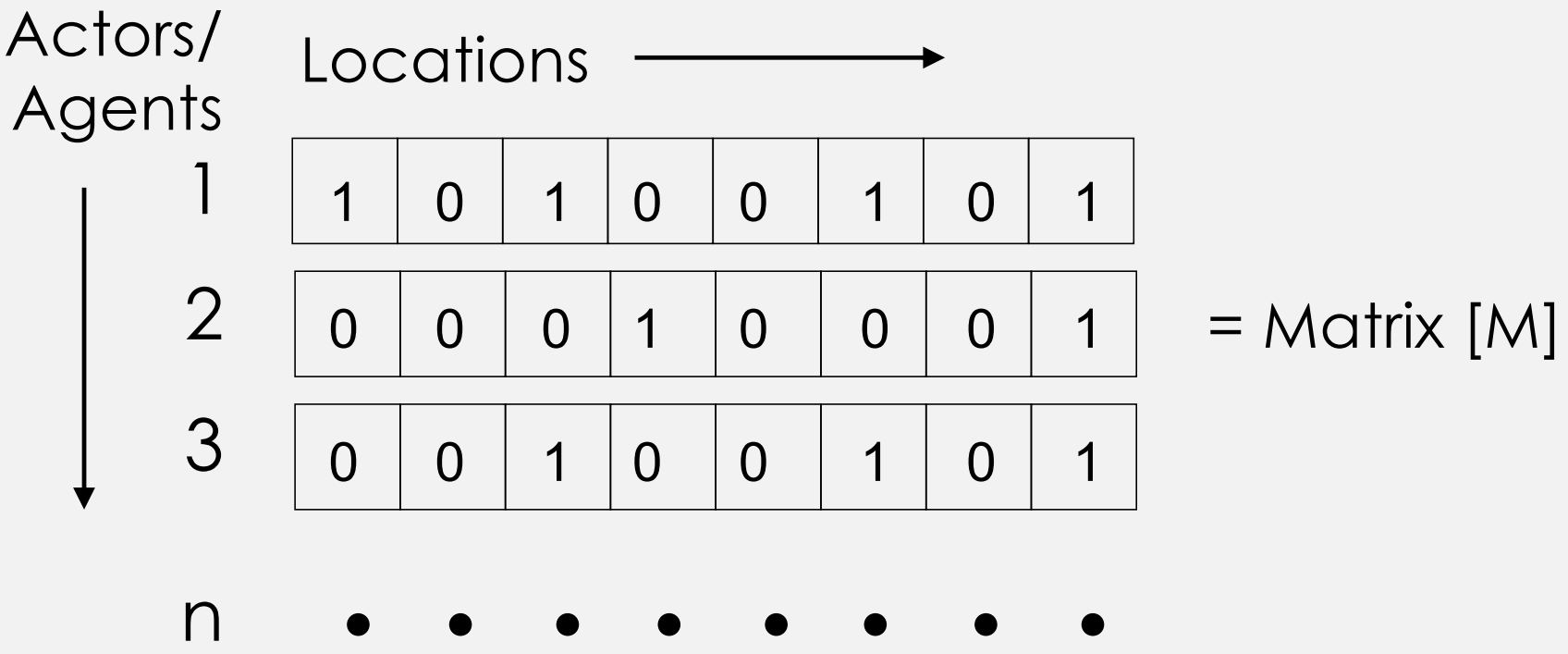
A More Elaborate Construction

- Now we first construct a network.
- Each map is coded on some desirability/utility scale –the simplest is 0 cannot be developed – 1 can be developed
- The maps conflict – represent the map as a vector

1	0	1
0	0	1
0	1	0



[1 0 1 0 0 1 0 1 0]



Note that I have dropped one cell in the map because my last example relates to 8 locations, not 9

The interactions between the agents can be seen in terms of the maps in the time-honoured way using the convention of forming the similarity or covariance

$$\begin{bmatrix} 3 & 1 & 3 & 3 & 3 & 1 \\ 1 & 1 & 1 & 1 & 1 & 0 \\ 3 & 1 & 3 & 3 & 3 & 1 \\ 3 & 1 & 3 & 5 & 4 & 2 \\ 3 & 1 & 3 & 4 & 7 & 2 \\ 1 & 0 & 1 & 2 & 2 & 2 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 \end{bmatrix}$$

$$A = M M^T$$

Now this is looking at links between agents through the maps – we can also look at links through the agents. The first problem we call the **primal**, the second the **dual**

$$\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 4 & 1 & 2 & 4 & 1 & 4 \\ 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 2 & 1 & 3 & 3 & 1 & 2 \\ 1 & 0 & 4 & 1 & 3 & 5 & 1 & 4 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 1 & 4 & 1 & 2 & 4 & 1 & 5 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix}$$

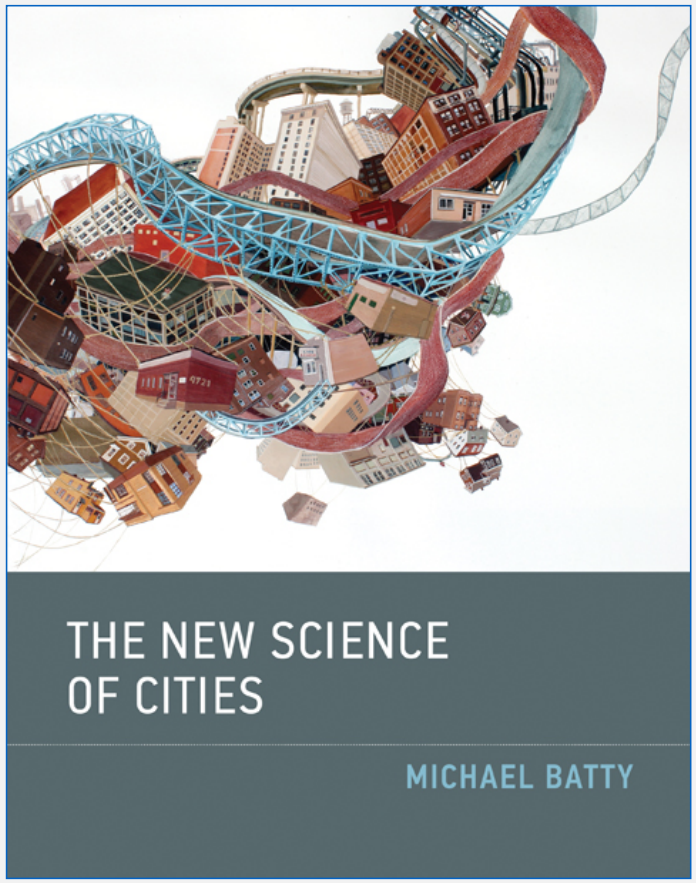
$$S = M^T M$$

Now there is quite a lot of algebra of these processes – if we consider the primal, the spatial averaging is a Markov chain – regular and connected and strong in the terminology

If we consider the averaging over agents for each site 0- the dual, this is also a Markov chain but a dual.

In fact I have written an entire book on this – or at least the third part of the book which no one ever reads is all about this. This is my ***The New Science of Cities*** book

And my first paper on this was written when …….



References over Many Years

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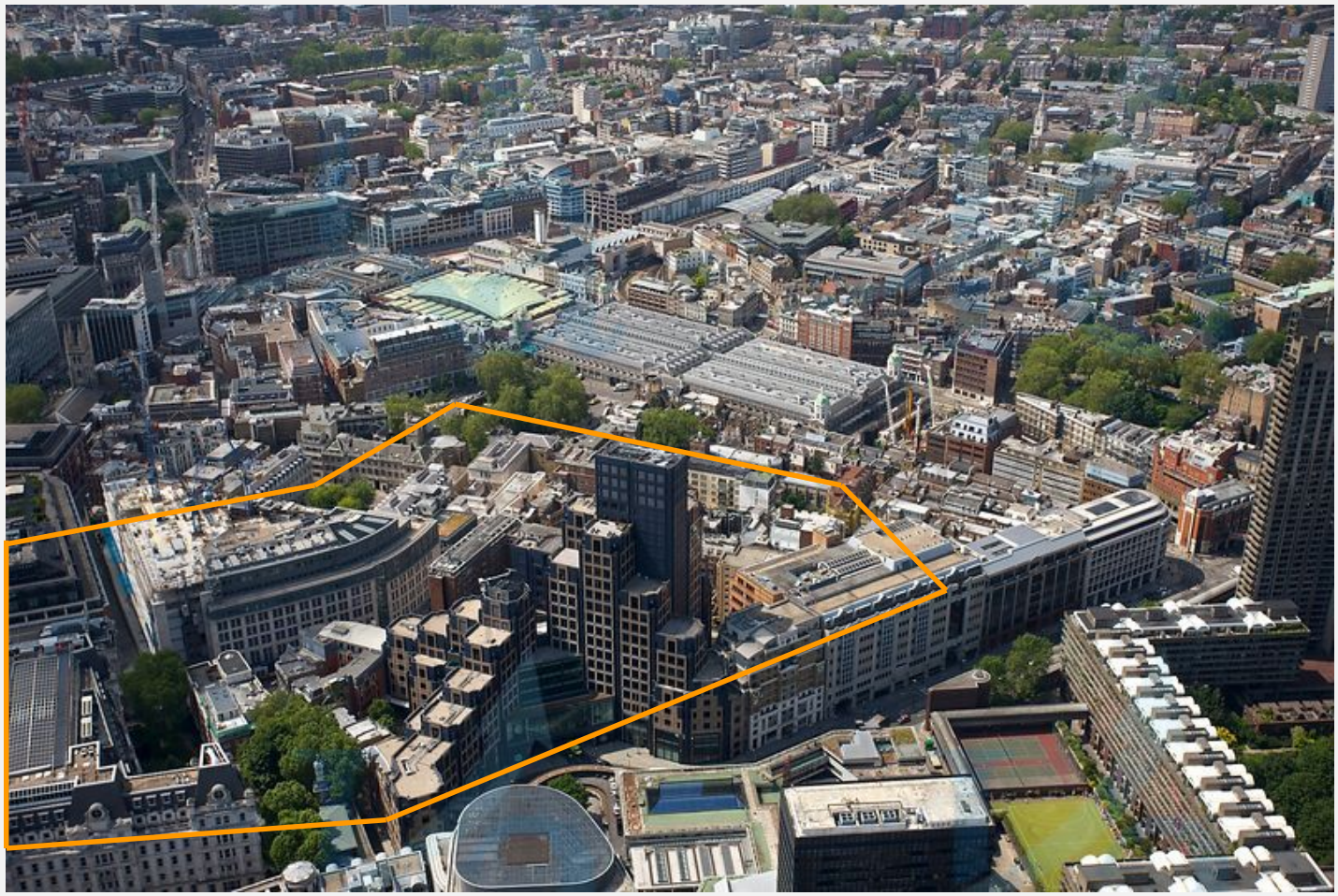
Batty, M. (1971) An Approach to Rational Design: Part 1: The Structure of Design Problems, Part 2: Design Problems as Markov Chains, **Architectural Design**, **41**, 436-439, 498-501

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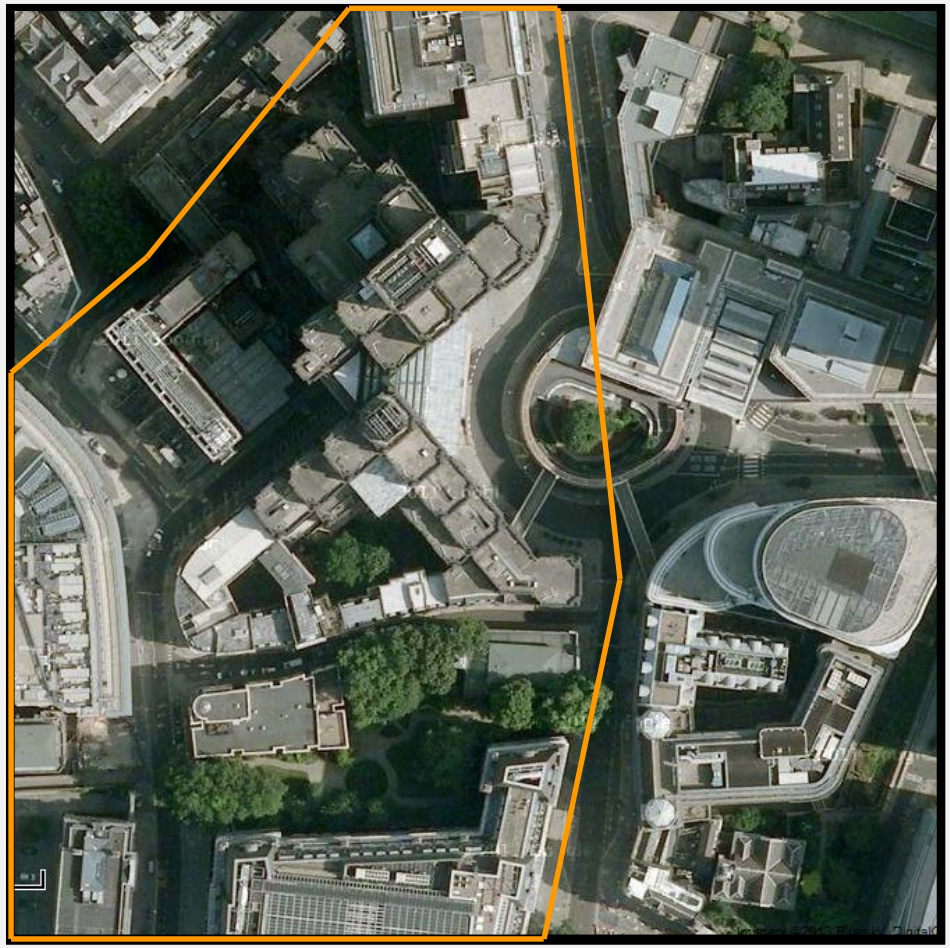
Blondel, V. D., Hendrickx, J. M., Olshevsky, A., and Tsitsiklis, J. N. (2005) Convergence in Multiagent Coordination, Consensus, and Flocking, In **Proceedings of the Joint 44th IEEE Conference on Decision and Control, European Control Conference**, Seville, Spain, December 12-15, 2005,

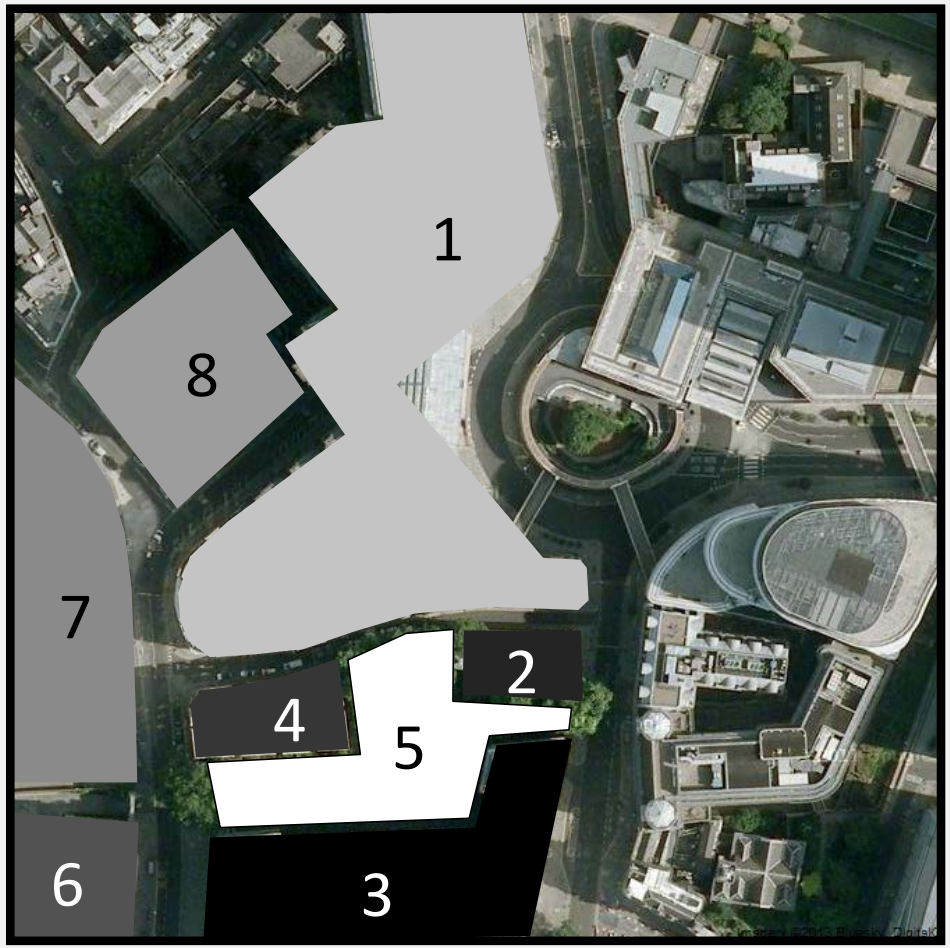
Batty, M. (2013) **The New Science of Cities**, MIT Press, Cambridge, MA

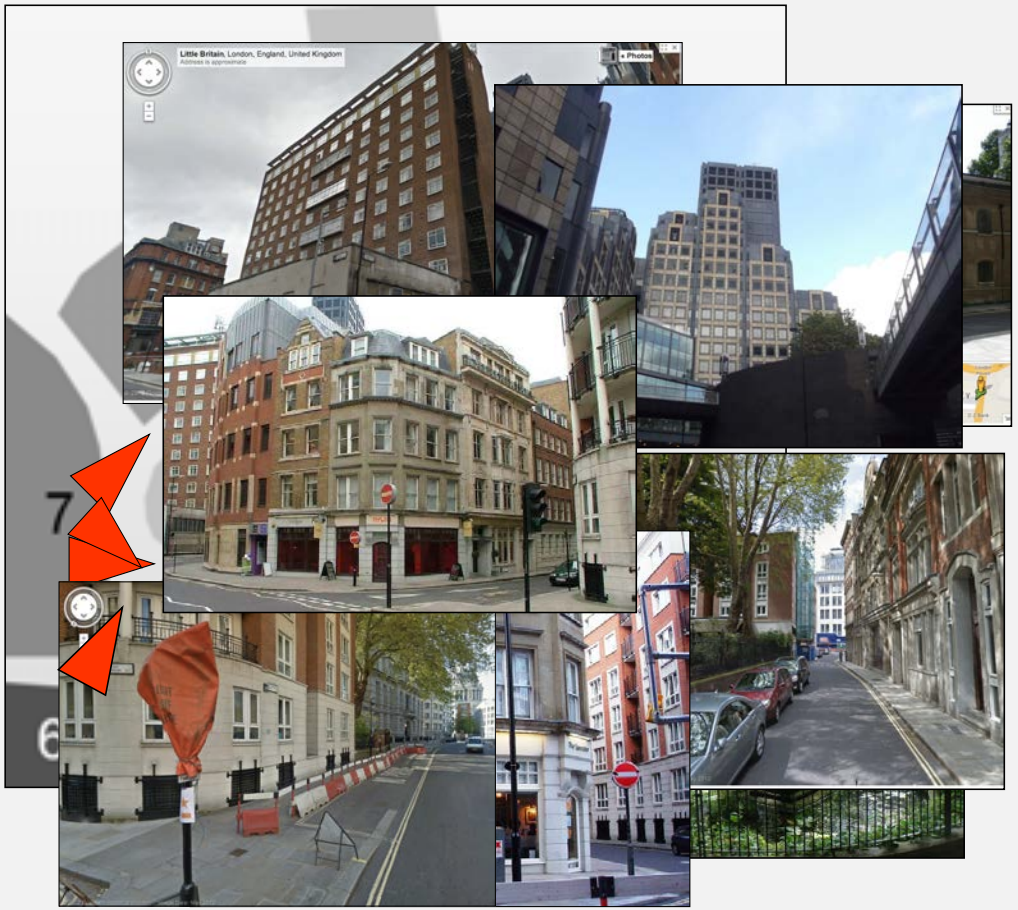
- Now I could finish here and not outstay my welcome but let me introduce one last example to show where this is going. This is a problem of development in the City of London – in the financial quarter where there is intense pressure to develop but intense control of the environment
- In fact it is so controlled that there are police cameras everywhere and a cordon around the City and no on-street parking and so on
- My example involves a small area near St. Paul's cathedral where there are 6 key actors and 8 sites.
- We want to figure the power of these actors in the problem



Planning as Conflict Resolution: 16th CUPUM Meeting at Wuhan




1
8
7
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Little Britain, London, England, United Kingdom

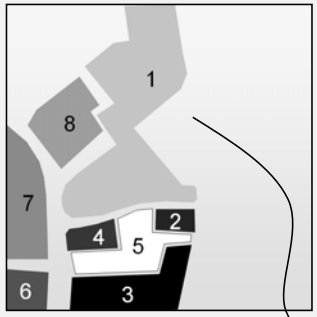


Actors/Stakeholders

1 City Corporation
2 Residents
3 Hospital NHS
4 Developers
5 Property Speculators
6 Banks

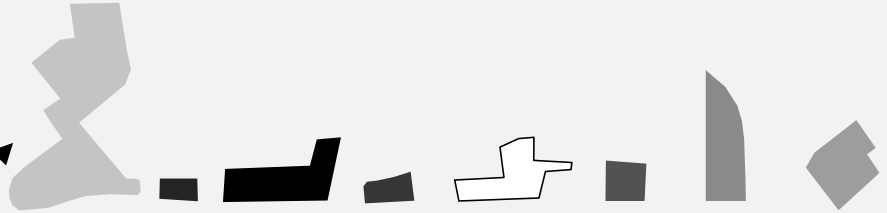
Sites/Buildings/Locations

1 Aldersgate Complex
2 St Botolph's
3 Nomura House
4 Milton House
5 Postman's' Park
6 Bank of America
7 Barts New Building
8 Barts Old Building



Sites/Buildings

1 2 3 4 5 6 7 8



Agents

1 City Corporation	0	0	1	0	0	1	0	1
2 Residents	0	0	0	0	0	0	0	1
3 Hospital NHS	0	0	1	0	0	1	0	1
4 Developers 5 Property Speculators 6 Banks	●	●	●	●	●	●	●	●

Sites/Buildings

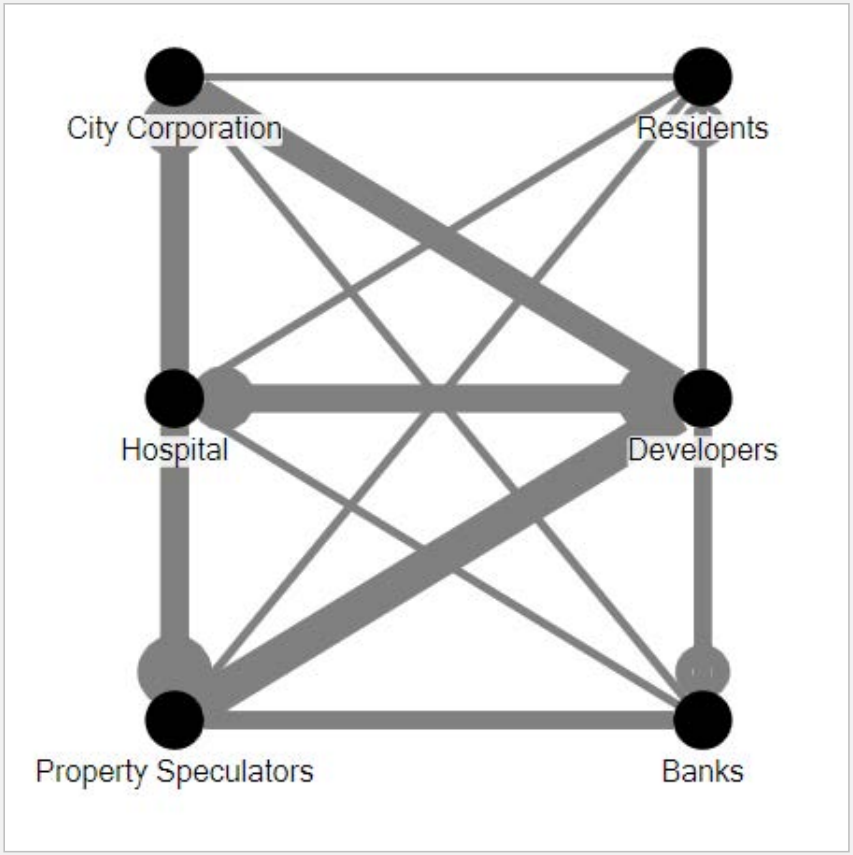
1 Aldersgate Complex
2 St Botolph's
3 Nomura House
4 Milton House
5 Postman's' Park
6 Bank of America
7 Barts New Building
8 Barts Old Building

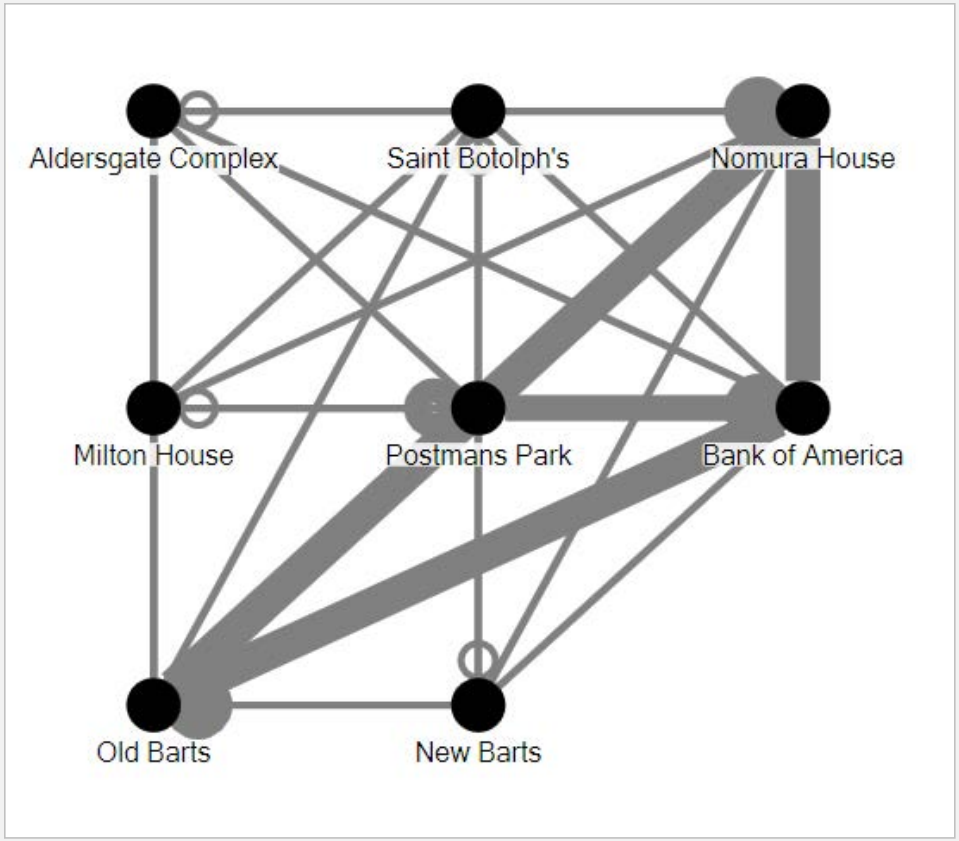


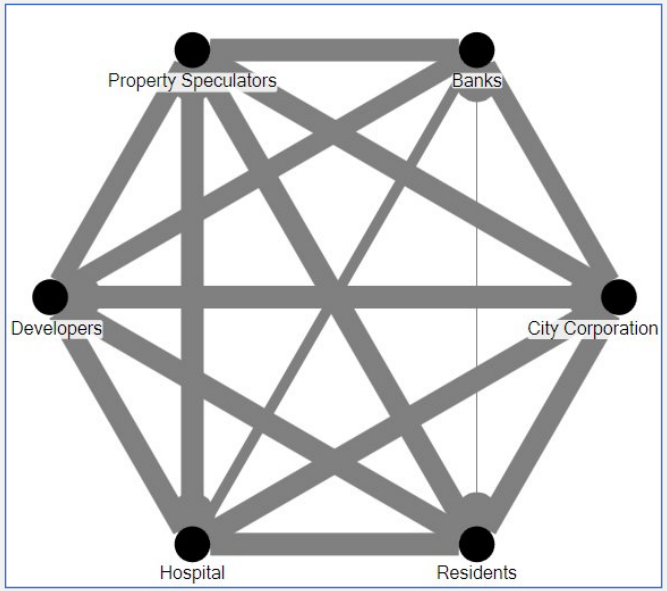
Agents

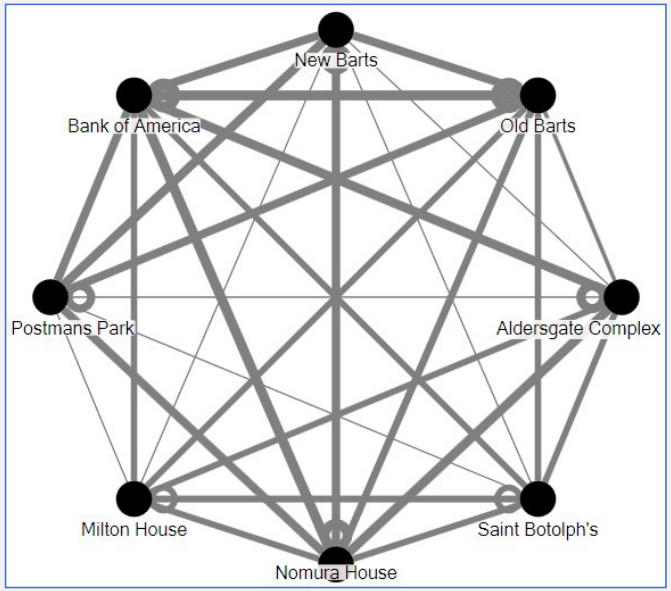
1 City Corporation
2 Residents
3 Hospital NHS
4 Developers
5 Property Spec
6 Banks

$$\begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix} = M$$


City Corporation
Residents
Hospital
Developers
Property Speculators
Banks


Aldersgate Complex
Saint Botolph's
Nomura House
Milton House
Postmans Park
Bank of America
Old Barts
New Barts


Property Speculators
Banks
Developers
City Corporation
Hospital
Residents


New Barts
Bank of America
Old Barts
Postmans Park
Aldersgate Complex
Milton House
Saint Botolph's
Nomura House

The Network Averaging X Set of Maps

$$\begin{bmatrix} 3/14 & 1/14 & 3/14 & 3/14 & 3/14 & 1/14 \\ 1/5 & 1/5 & 1/5 & 1/5 & 1/5 & 0 \\ 3/14 & 1/14 & 3/14 & 3/14 & 3/14 & 1/14 \\ 3/18 & 1/18 & 3/18 & 5/18 & 4/18 & 2/18 \\ 3/20 & 1/20 & 3/10 & 4/20 & 7/20 & 2/20 \\ 1/8 & 0 & 1/8 & 2/8 & 2/8 & 2/8 \end{bmatrix} \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix}$$

yields

A New Averaged Set of Maps

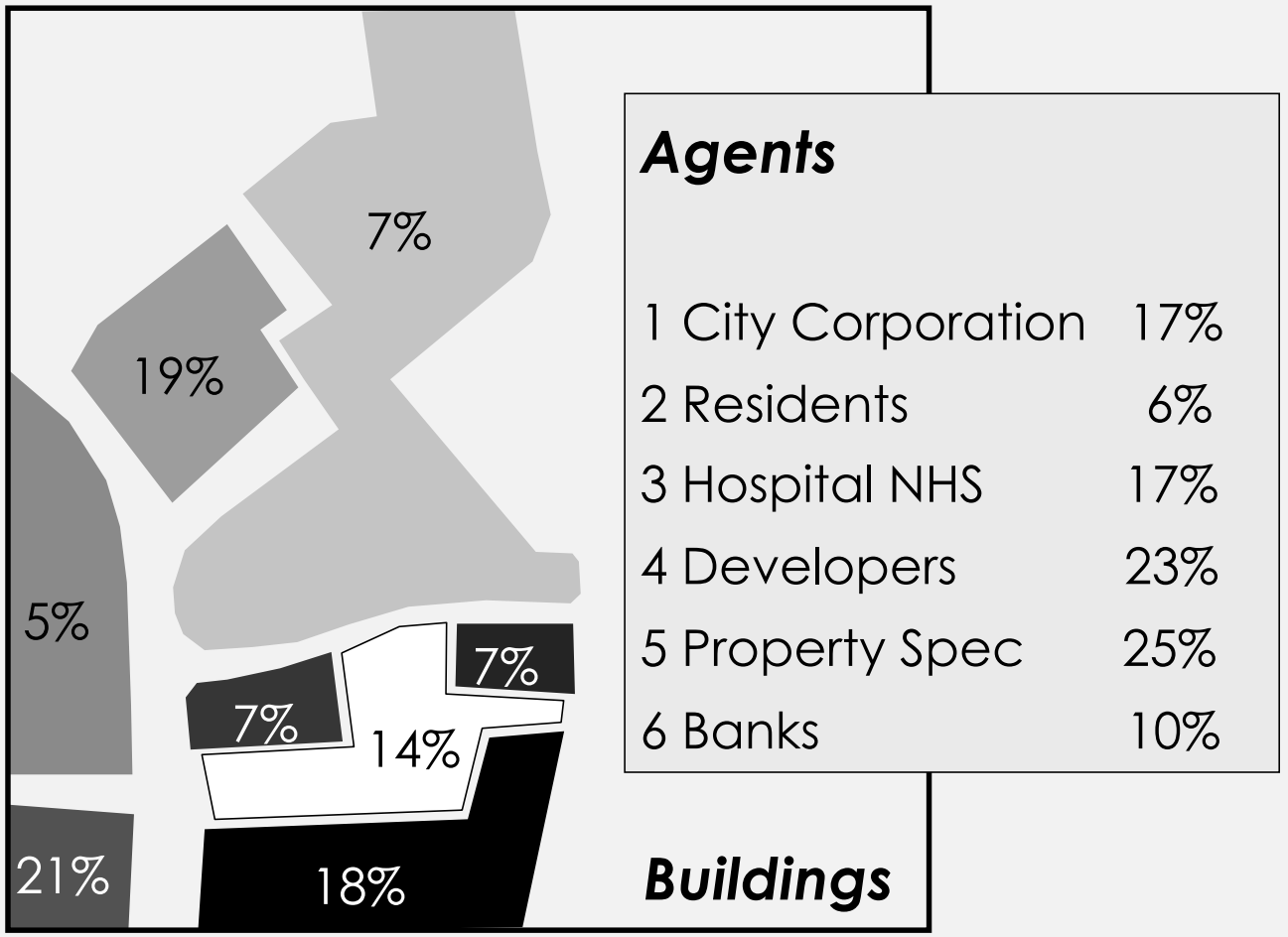
$$\begin{bmatrix} 0.21 & 0.21 & 0.86 & 0.21 & 0.50 & 0.93 \\ 0.20 & 0.20 & 0.80 & 0.20 & 0.40 & 0.80 \\ 0.21 & 0.21 & 0.86 & 0.21 & 0.50 & 0.93 \\ 0.22 & 0.22 & 0.83 & 0.22 & 0.61 & 0.94 \\ 0.35 & 0.35 & 0.85 & 0.35 & 0.65 & 0.95 \\ 0.25 & 0.25 & 0.75 & 0.25 & 0.75 & 1.00 \end{bmatrix}$$

And then we average them again using the same network
And this yields a new map, And so on until all the differences between the actors with respect to their maps are ironed out and we get the following map

0.25	0.25	0.84	0.25	0.58	0.94
0.25	0.25	0.84	0.25	0.58	0.94
0.25	0.25	0.84	0.25	0.58	0.94
0.25	0.25	0.84	0.25	0.58	0.94
0.25	0.25	0.84	0.25	0.58	0.94
0.25	0.25	0.84	0.25	0.58	0.94

We can do this on the dual problem, on the sites and iron out the differences between sites with respect to their actors

I do not have time to explain the problem in detail but here are the results for the relative power & interest of actors and sites in the problem


7%
19%
5%
7%
7%
14%
21%
18%
Agents
1 City Corporation 17%
2 Residents 6%
3 Hospital NHS 17%
4 Developers 23%
5 Property Spec 25%
6 Banks 10%
Buildings

Thanks for listening

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