

Analyzing C2 Structures and Self-Synchronization with Simple Computational Models

Paper 010



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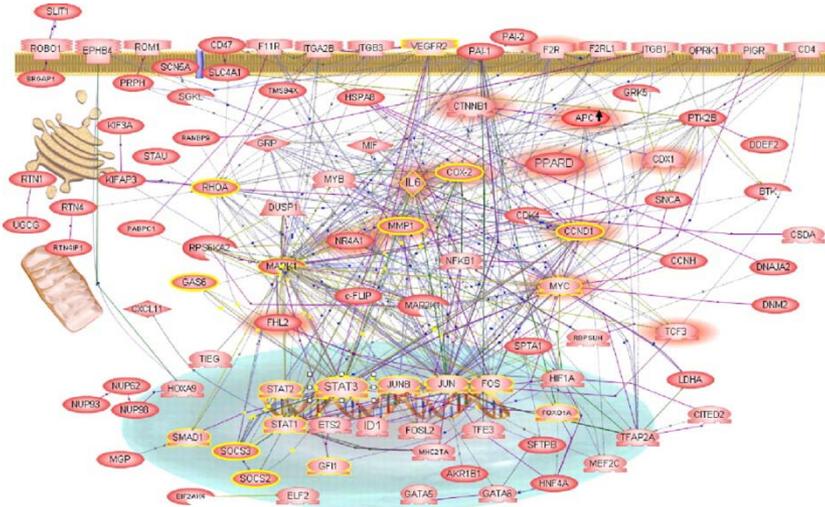


Australian Government

Department of Defence

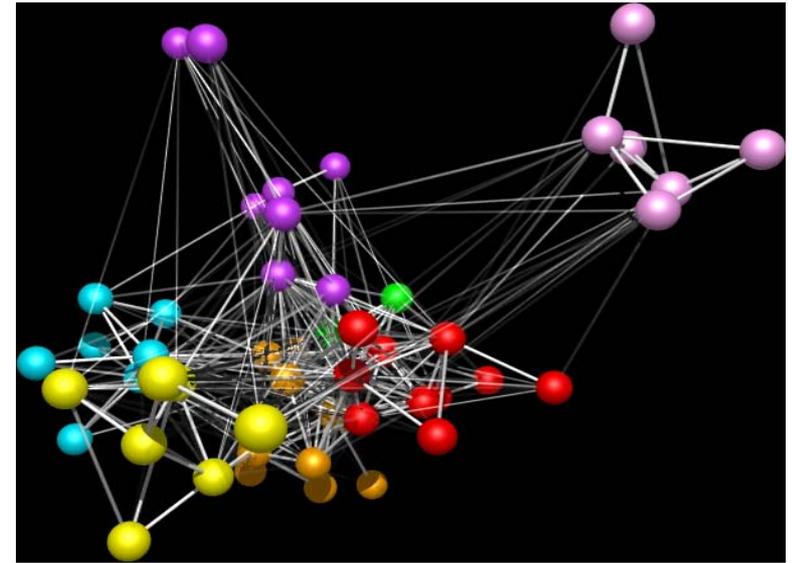
Defence Science and
Technology Organisation

Self-Synchronisation in Networks

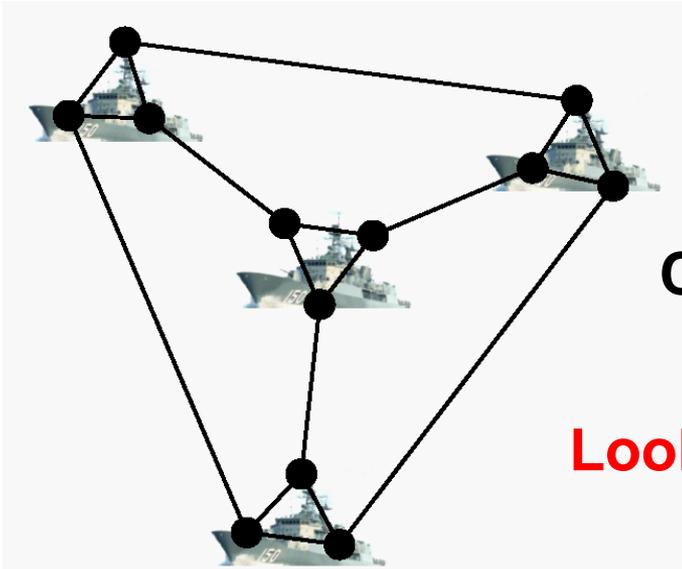


Genetic Networks

www.pnas.org/content/104/31/12890/F2.large.jpg



Organisational Networks



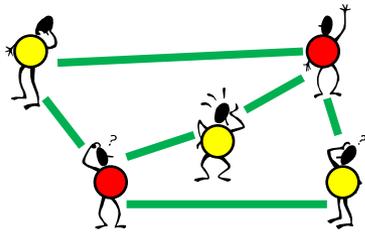
C2 Networks

Looking for fundamental network principles

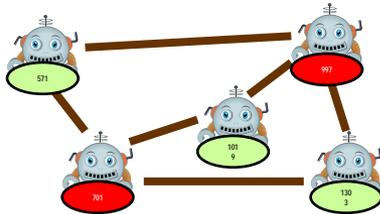
Overview of this talk



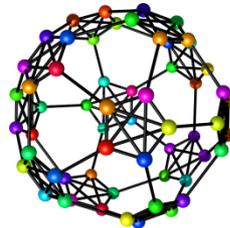
Synchronisation with Humans: ELICIT



Humans #2: Network Colouring



Simulation: The Factoring Problem



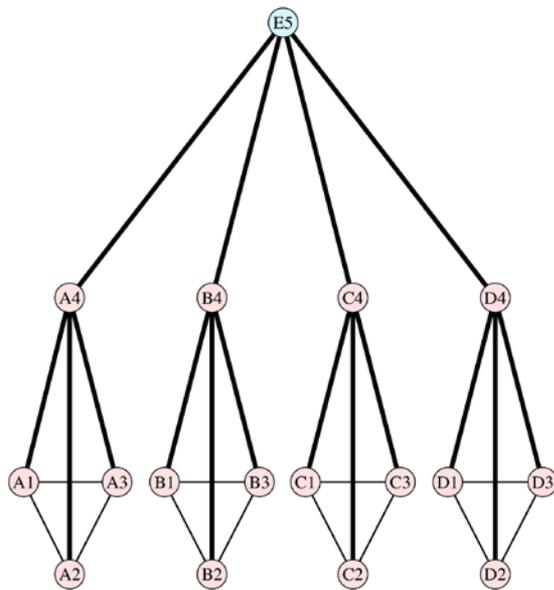
Simulation #2: Kuramoto Model



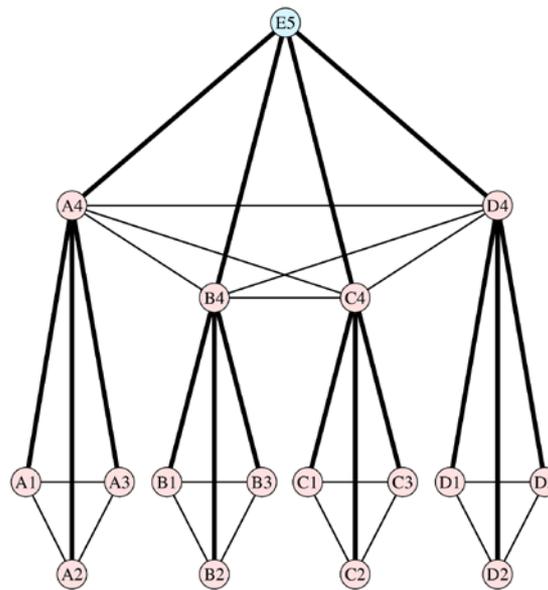
A Dilemma & Future Work

Synchronisation with humans: ELICIT

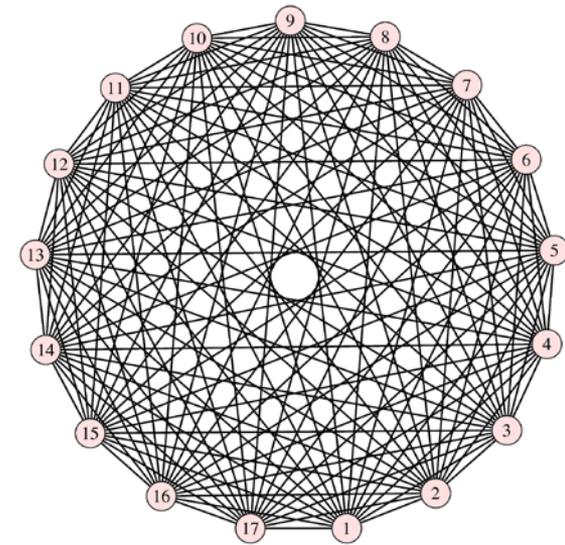
Team decision-making using different organisational structures



(a) Traditional Hierarchy



(b) Hybrid Organization

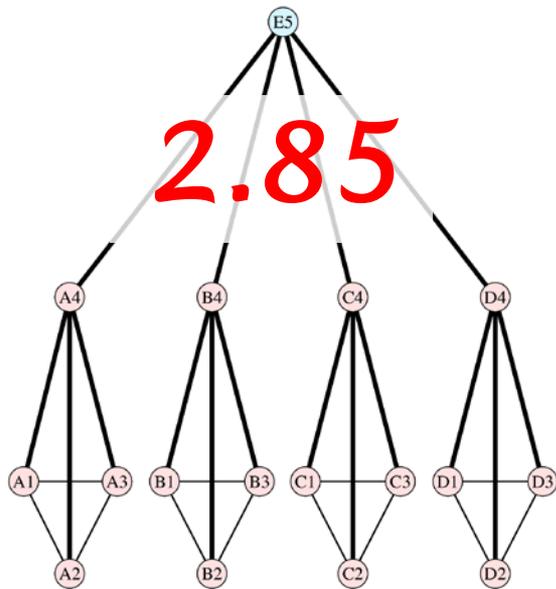


(c) Edge Organization

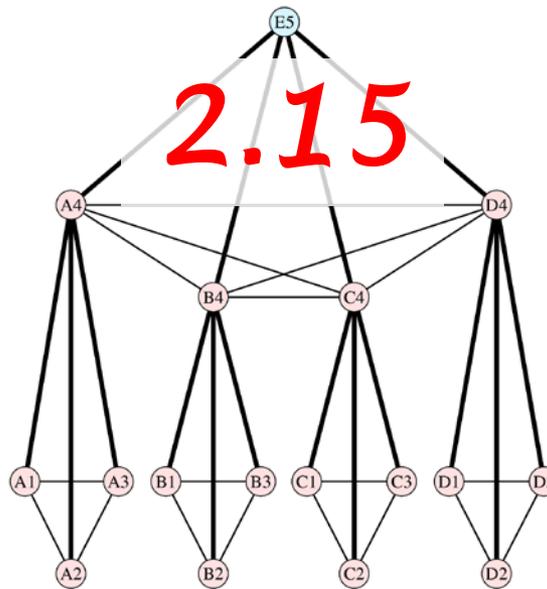
See P. Thunholm, E.-C. Ng, M. Cheah, K.-Y. Tan, N. Chua, and C.-L. Chua, “Exploring Alternative Edge versus Hierarchy C2 Organizations using the ELICIT Platform with Configurable Chat System.” *International C2 Journal*. 3(2), 2009, www.dodccrp.org/files/IC2J_v3n2_04_Thunholm.pdf

Synchronisation with humans: ELICIT

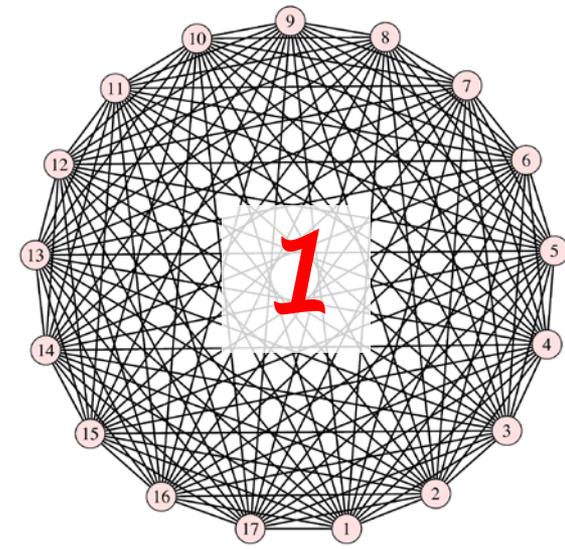
The three organisational structures have different average distances = average number of “hops” between people



(a) Traditional Hierarchy

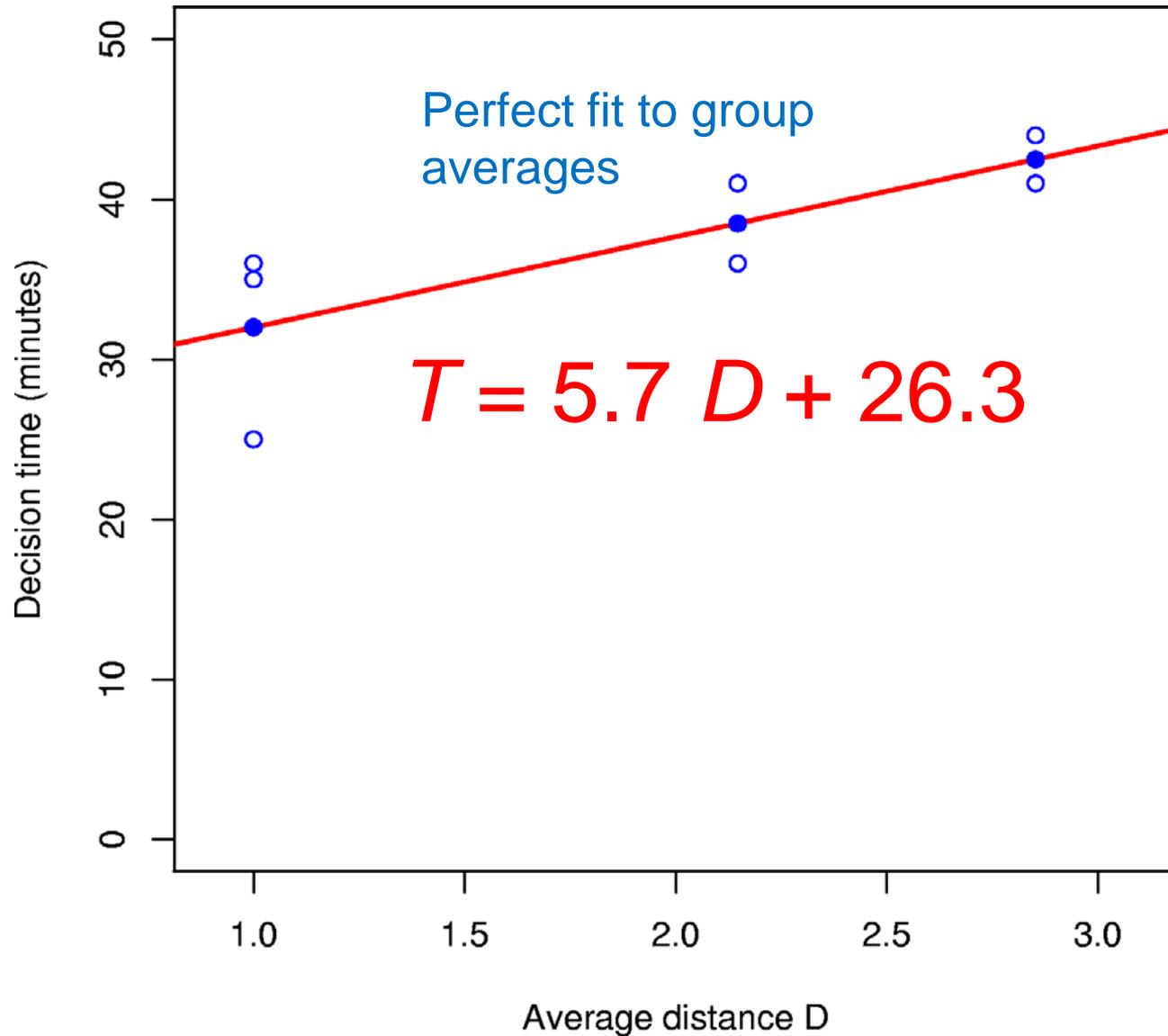


(b) Hybrid Organization



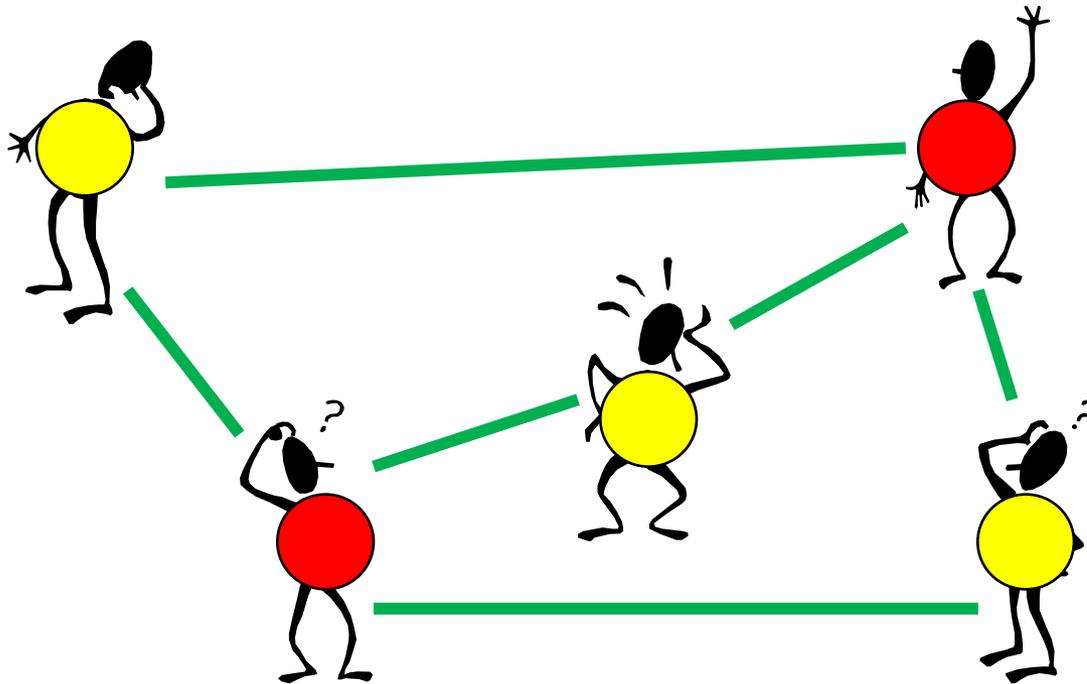
(c) Edge Organization

Decision time depends on average distance



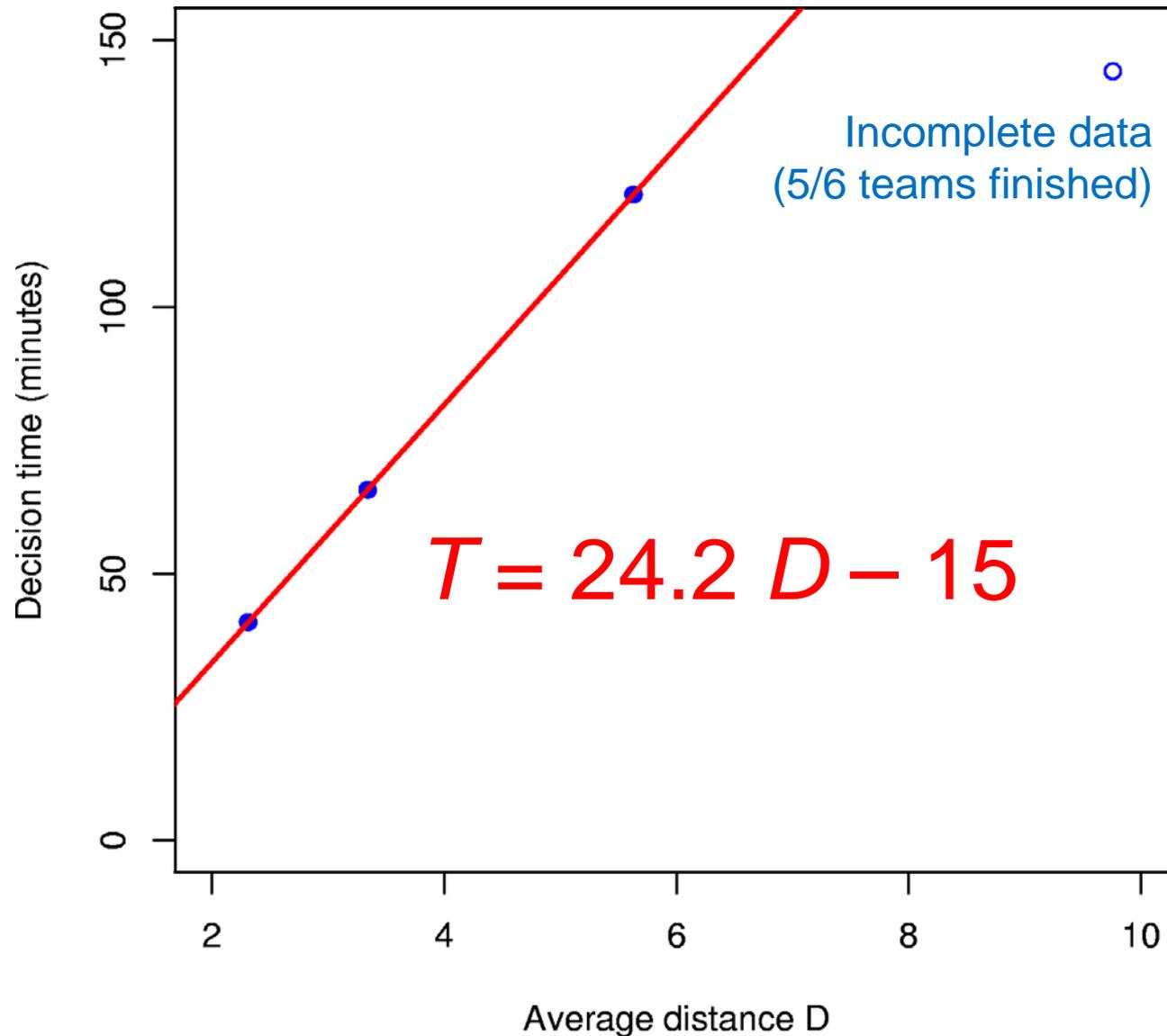
Humans #2: The colouring problem

Team-members must choose colours such that network neighbours always have different colours
– no talking, only observing colours of neighbours

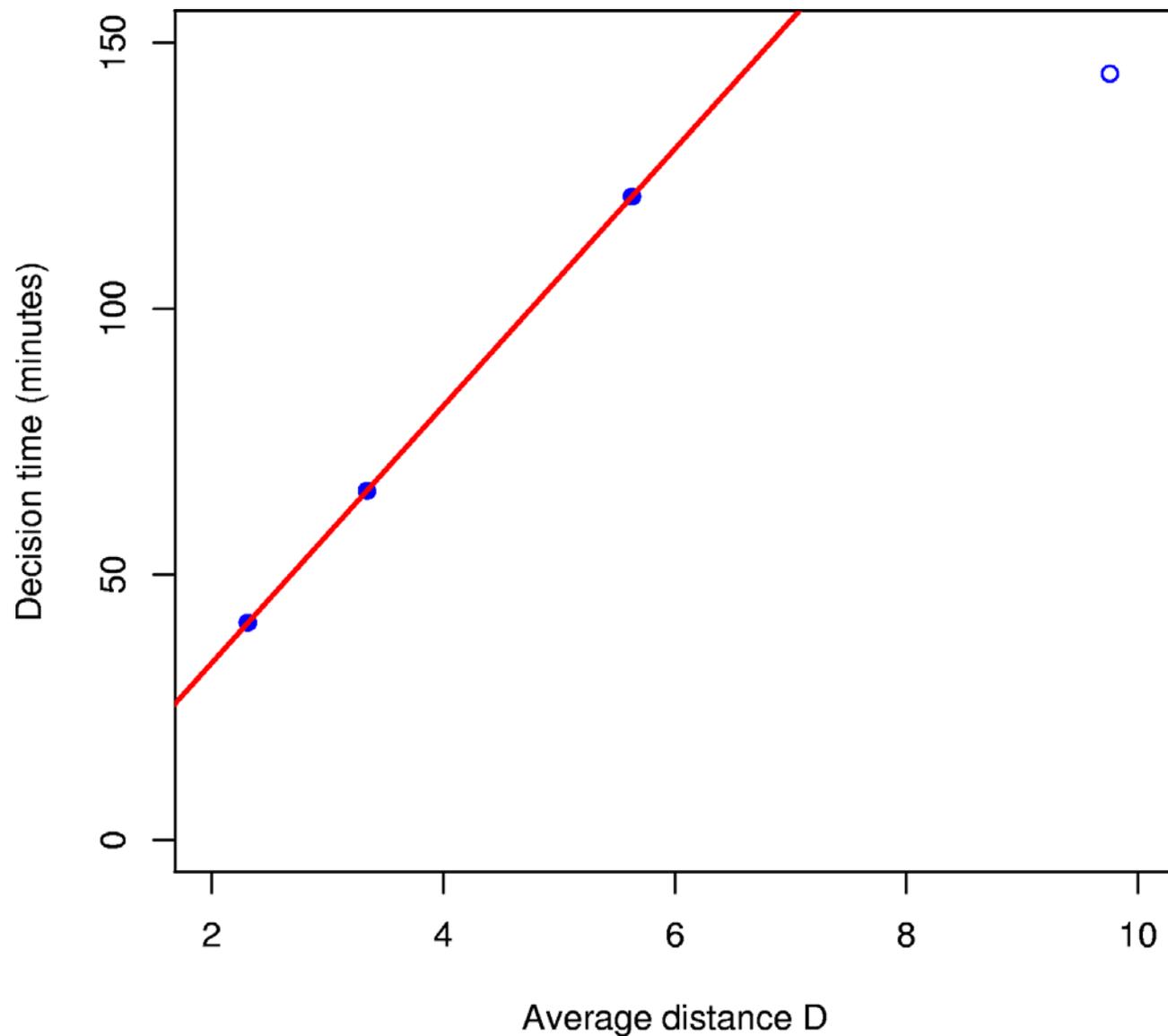
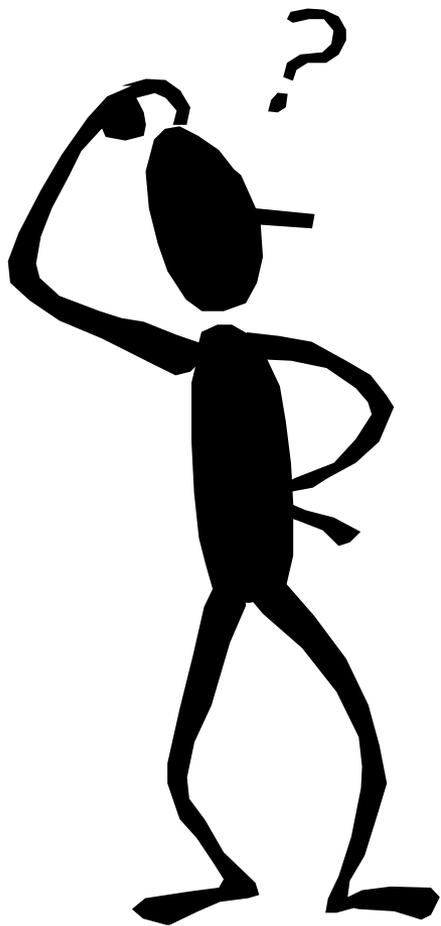


See www.cis.upenn.edu/~mkearns/ and Kearns, M., Suri, S., & Montfort, N. (2006) "An Experimental Study of the Coloring Problem on Human Subject Networks," *Science*, Vol. 313, 11 August, pp 824–827

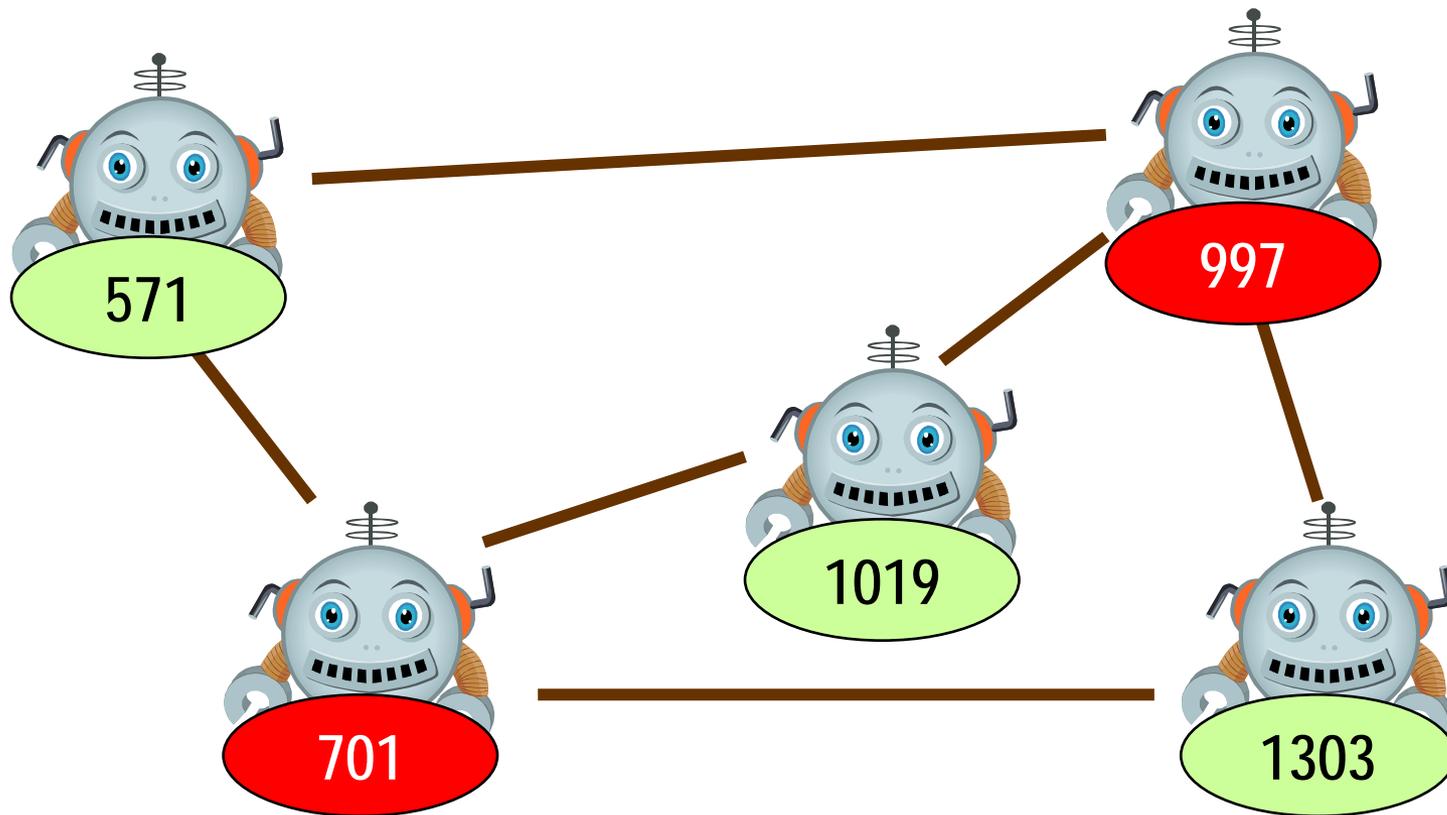
Decision time again depends on average distance



Is the linear distance/time relationship a general rule?



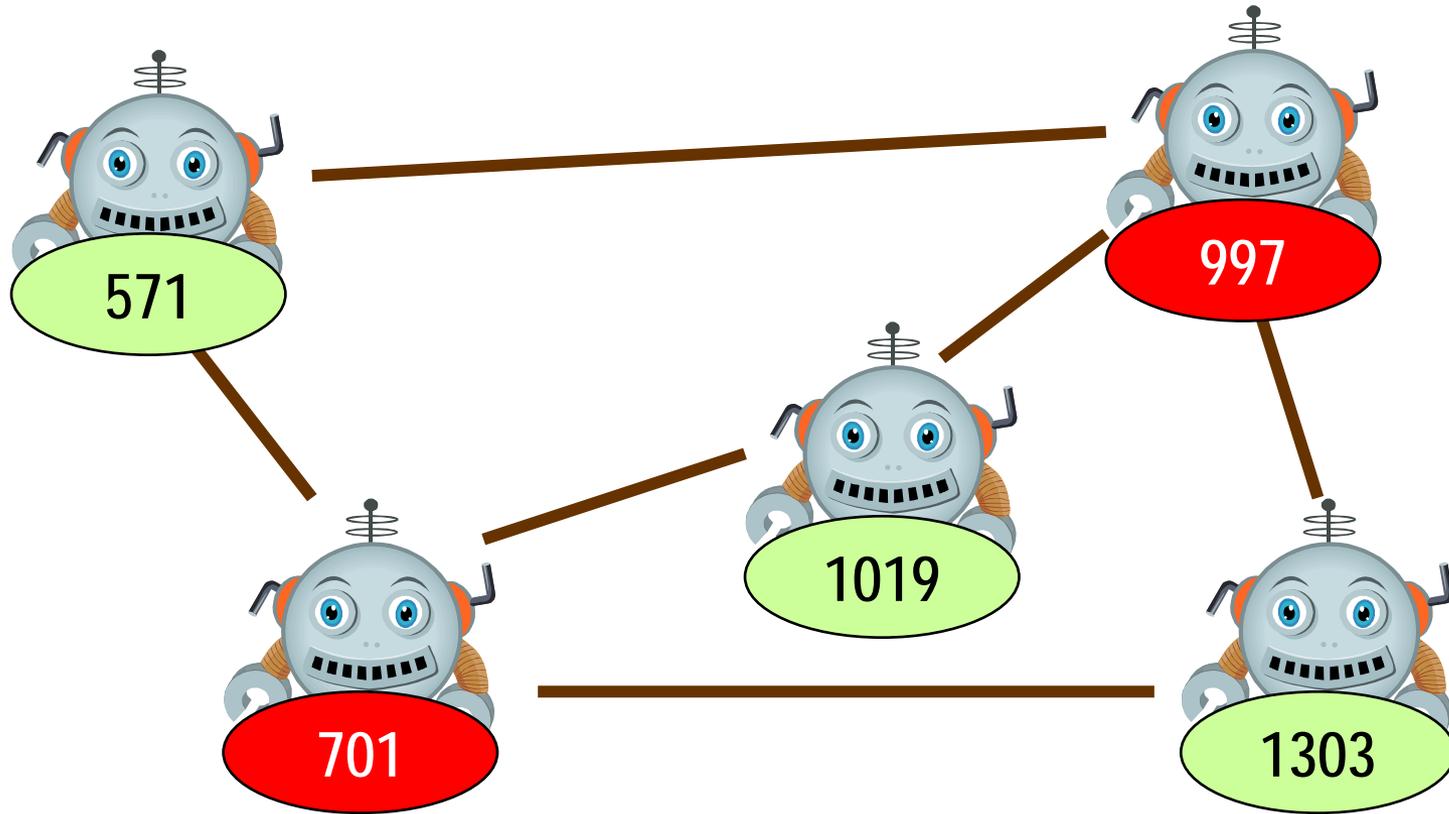
Factoring with Agent Networks ...



Agents use trial and error to factor a large number

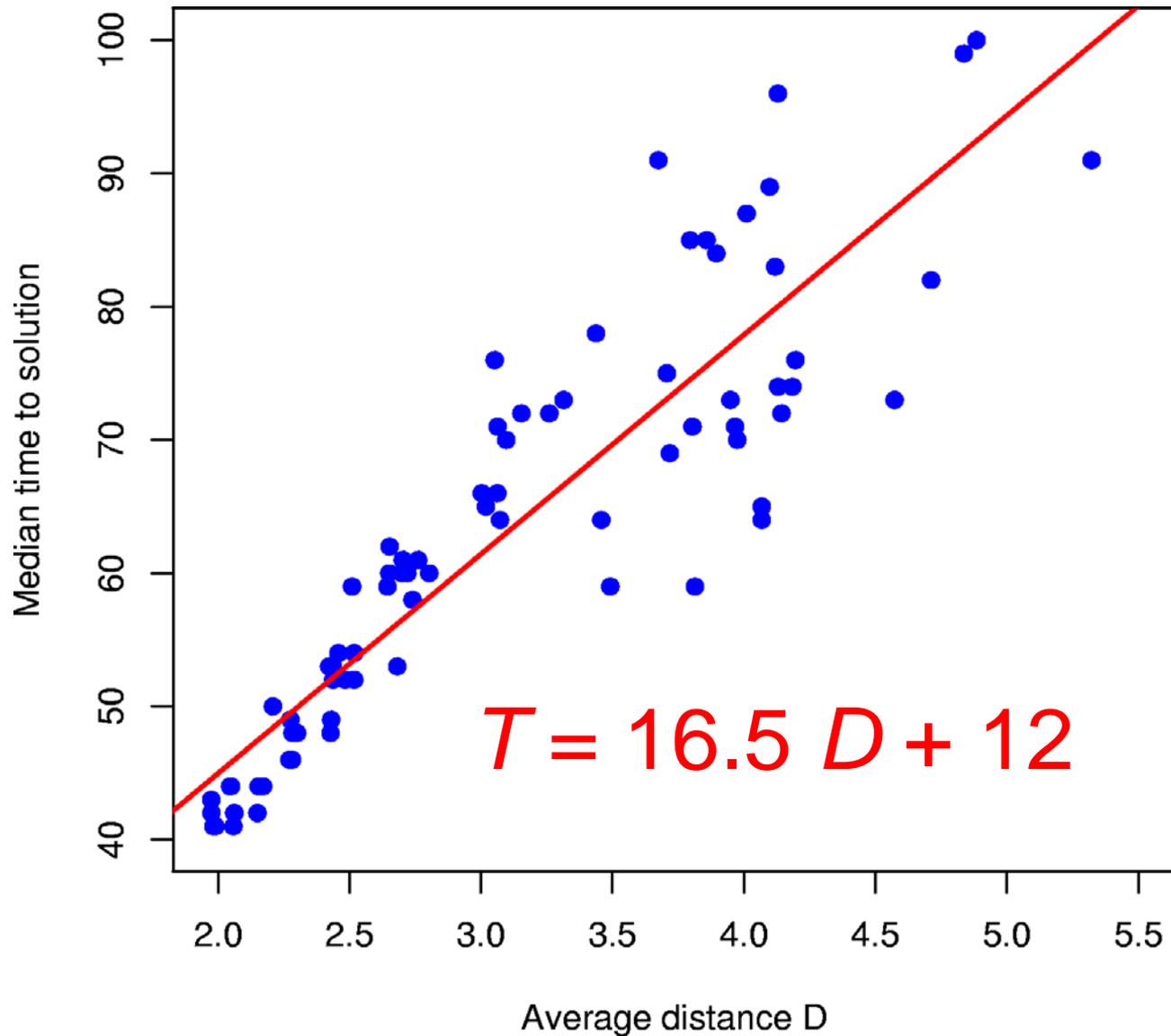
e.g. $6,598,886,315,082,427 = 571 \quad 1,019 \quad 1,303 \quad 2,371 \quad 3,671$

... is a very simple model of Collaborative Planning

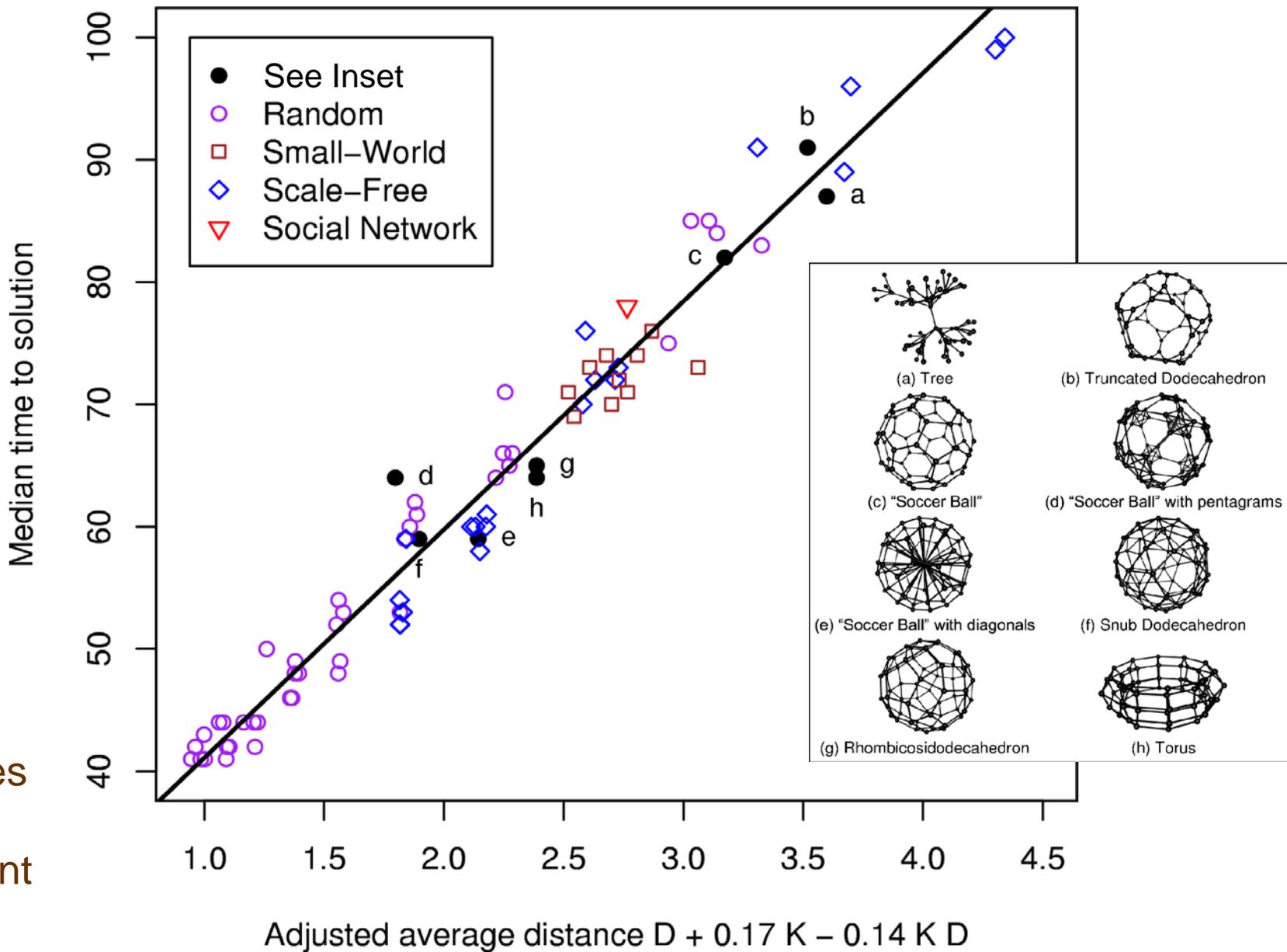


- Agents exchange messages about factors they have found
- Agents also forget information at a steady rate
- The team finishes when all agents have the complete answer

Experiments show a linear distance/time relationship

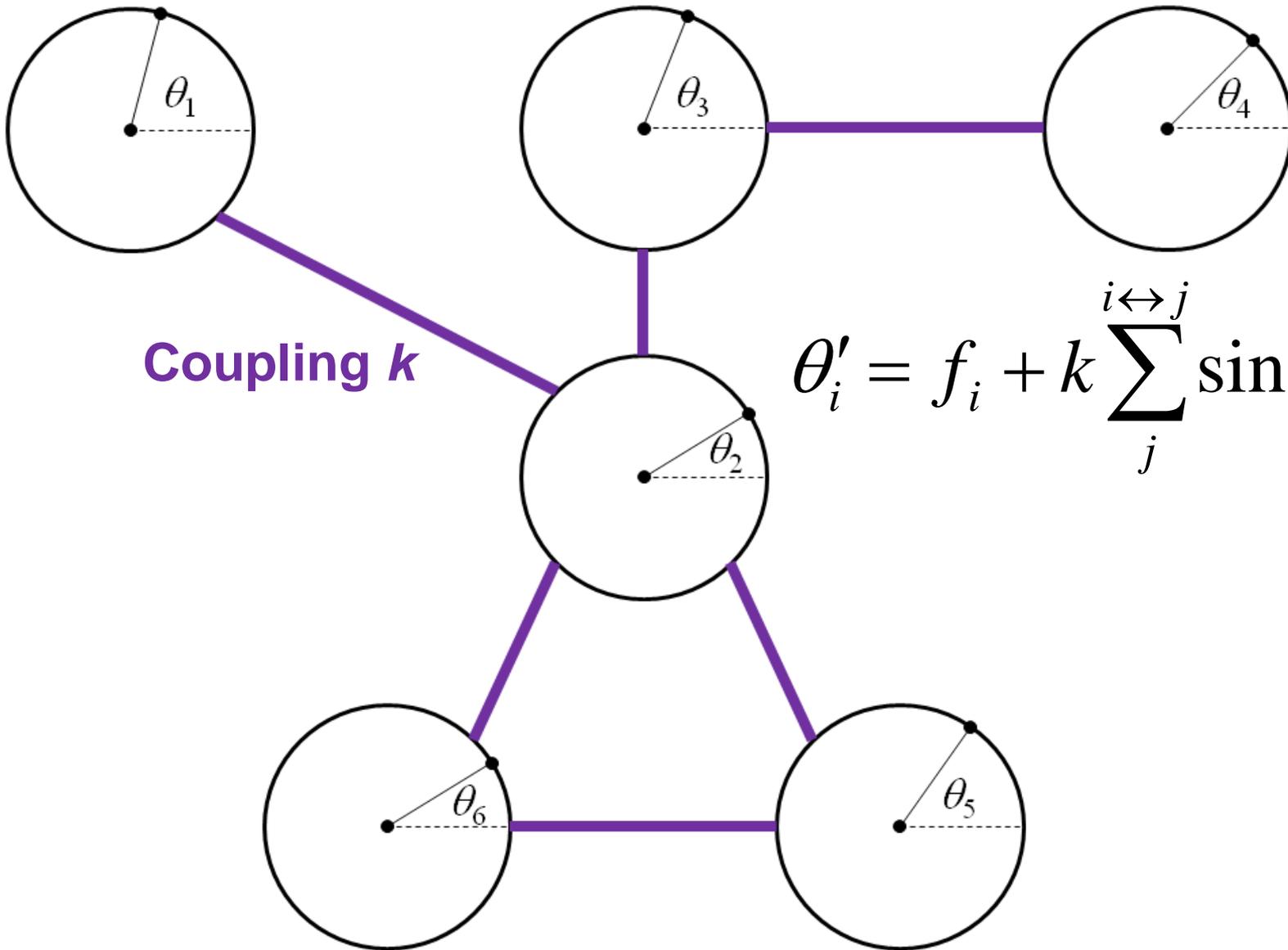


Multiple independent pathways also reduce time



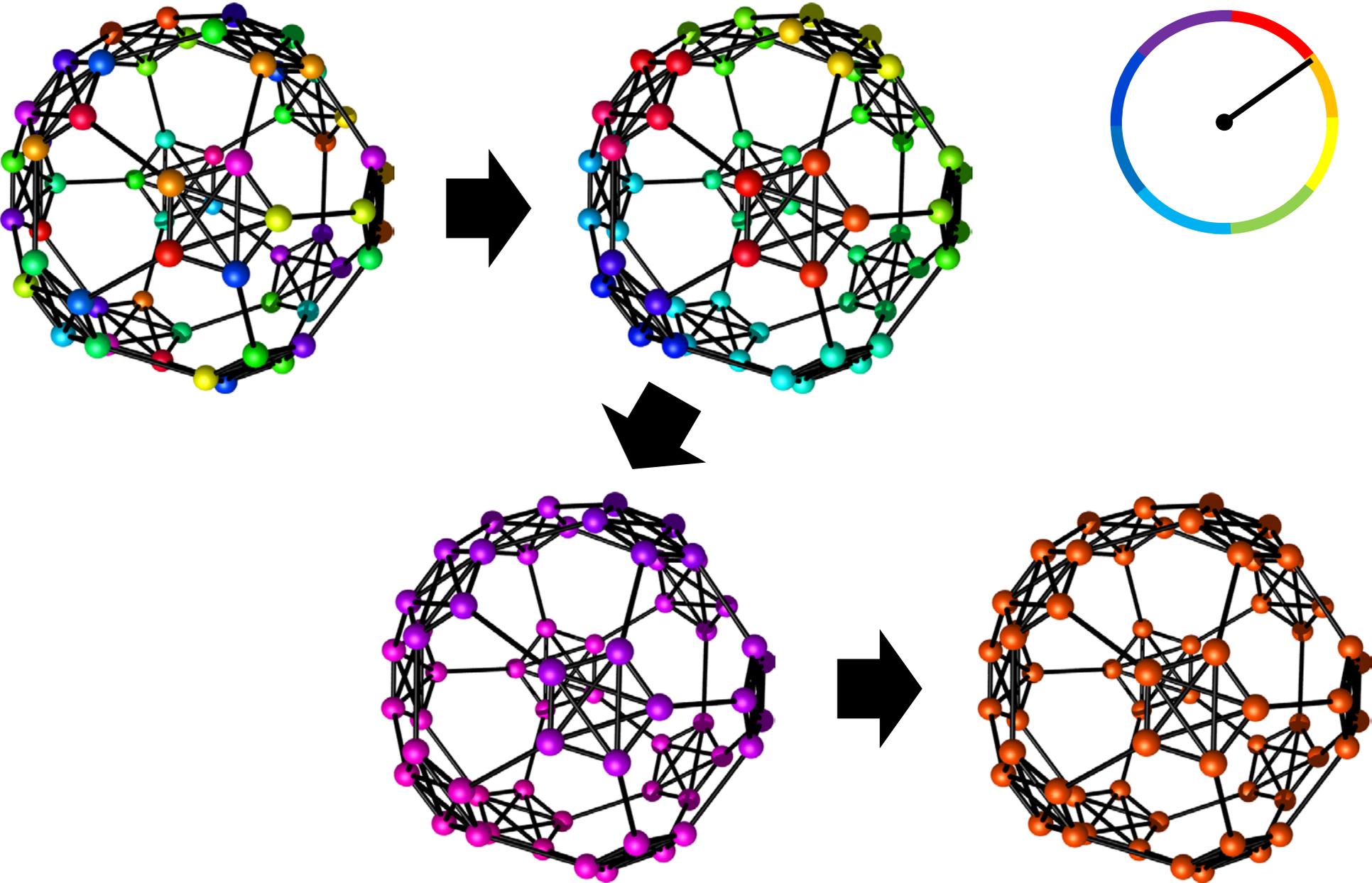
K measures number of independent pathways

Using the Kuramoto Model to study Synchronisation

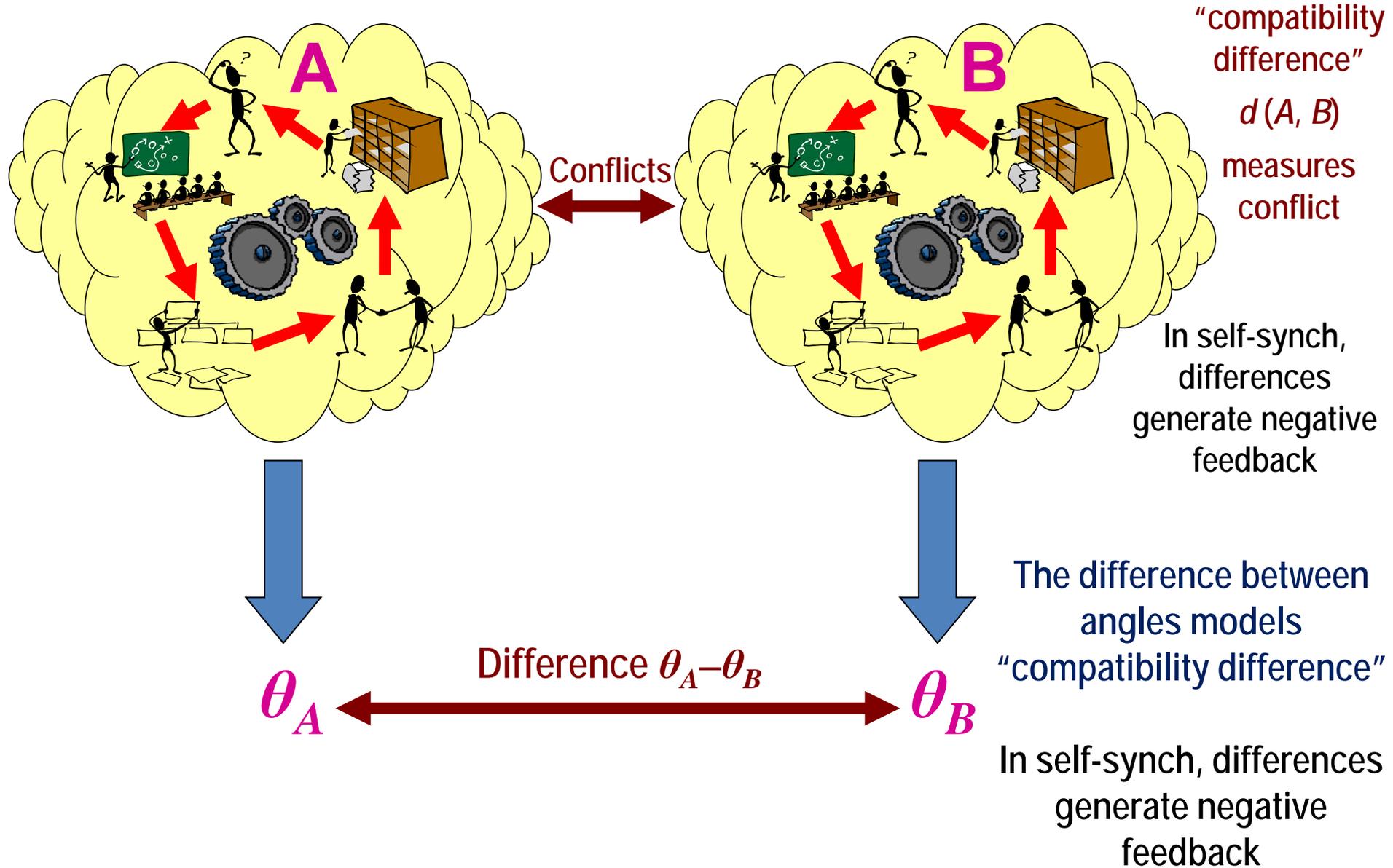


$$\theta'_i = f_i + k \sum_j^{i \leftrightarrow j} \sin(\theta_j - \theta_i)$$

Networks synchronise as the phase angles θ_i align

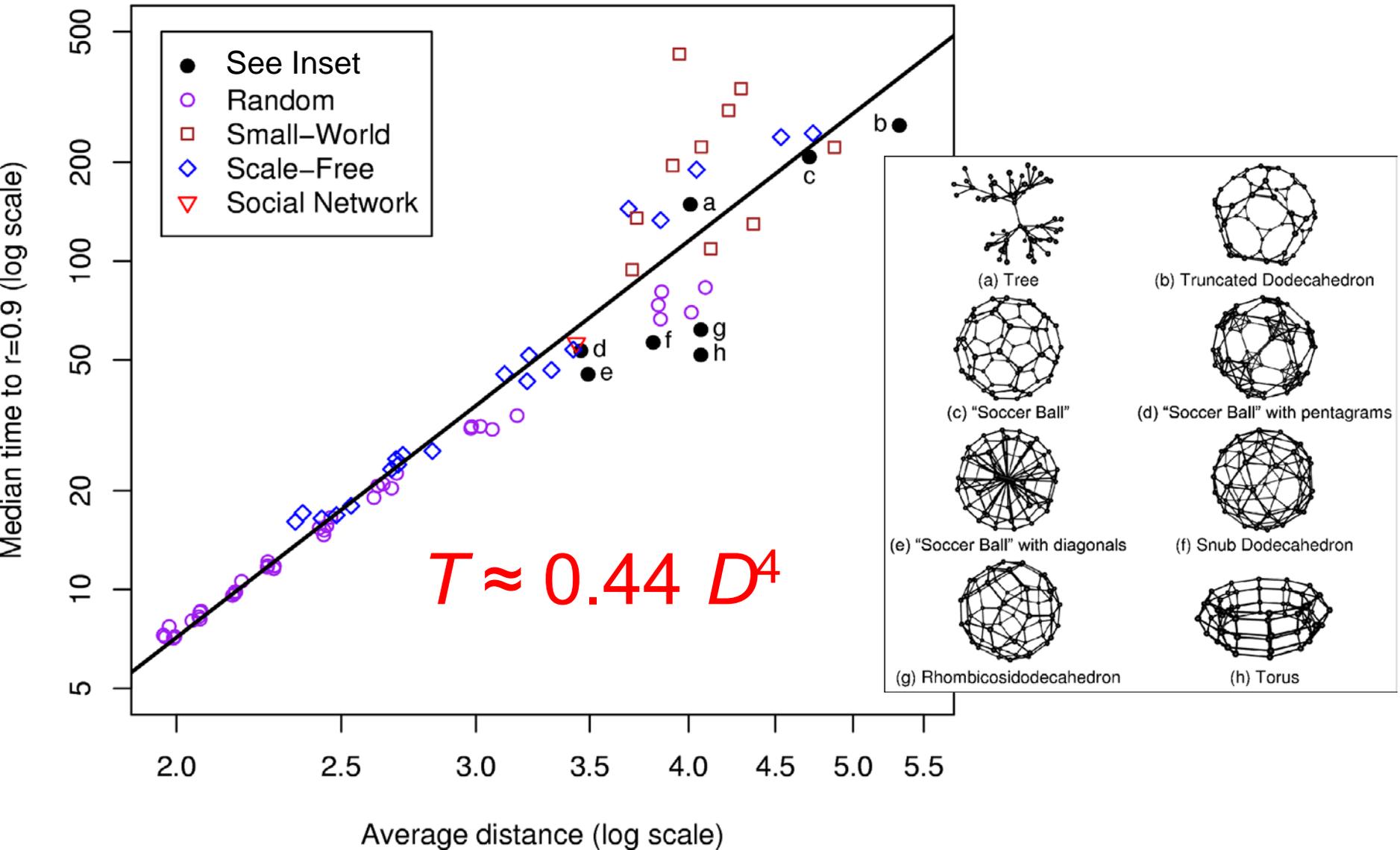


Kuramoto model can represent self-synchronisation

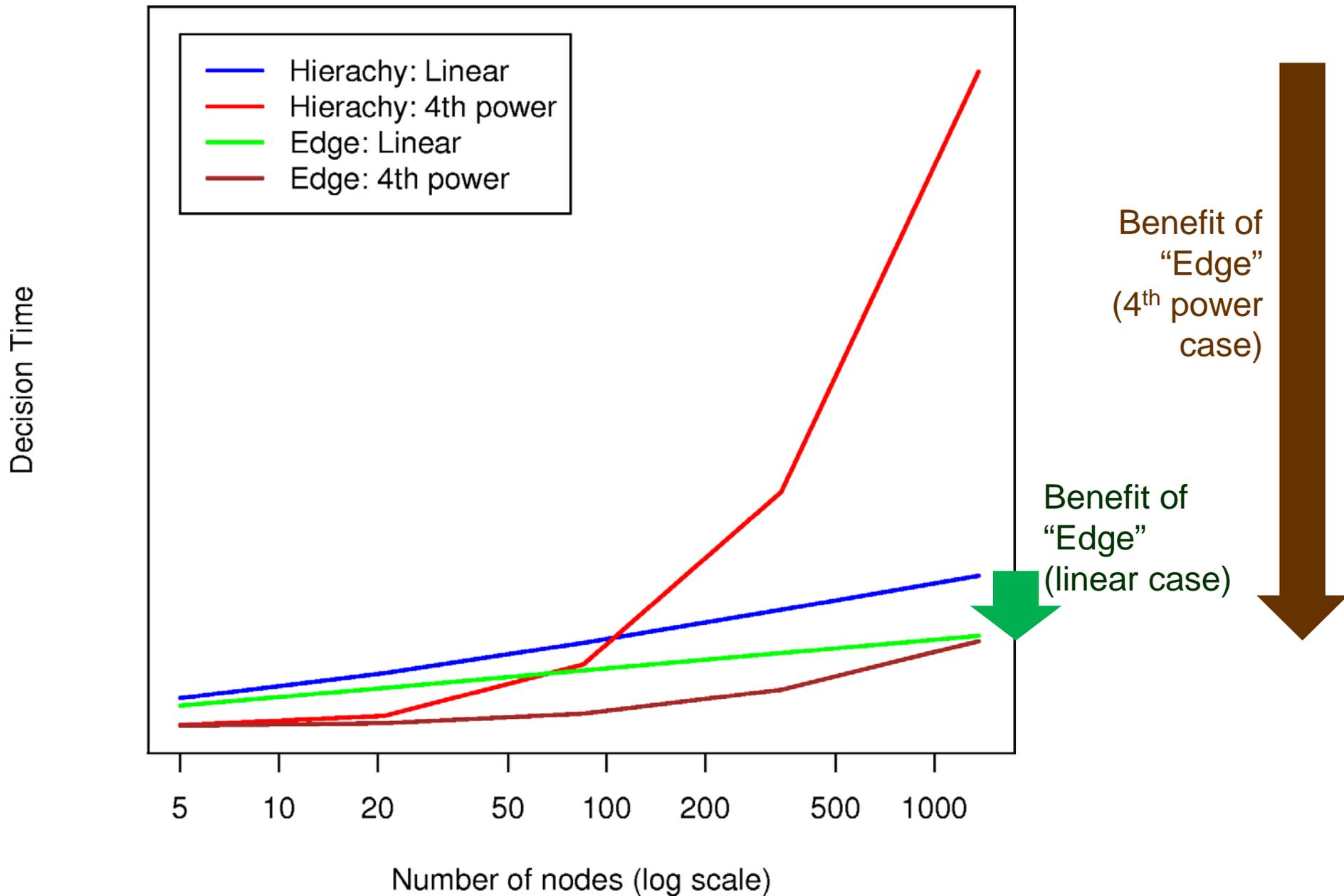


... but this time there's a power-law relationship

Prediction of synchronisation for some 60-node networks



If time depends on D^4 , an "Edge" structure is very good



Why the difference? Does T depend on D or D^4 ?

Is it a modelling artifact? Does it simply reflect the specifics of the Kuramoto model?

Or does it reflect the attenuation/decay of information in transit across the network?

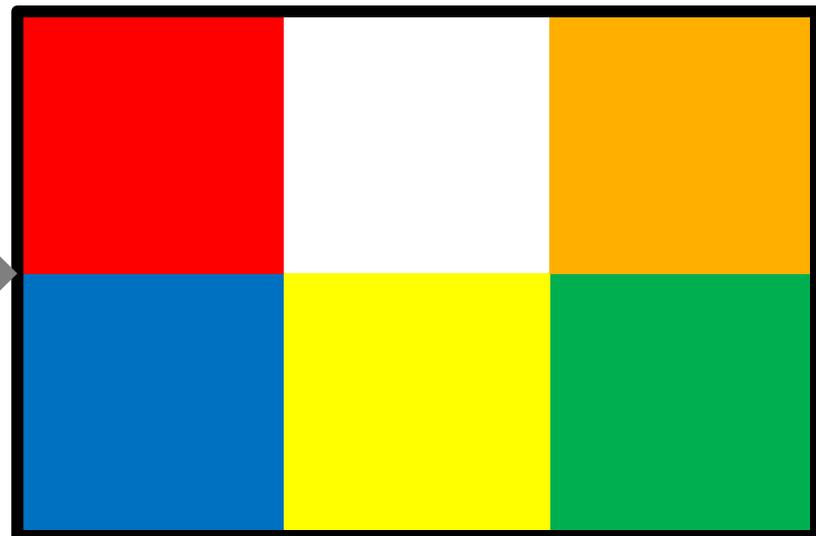
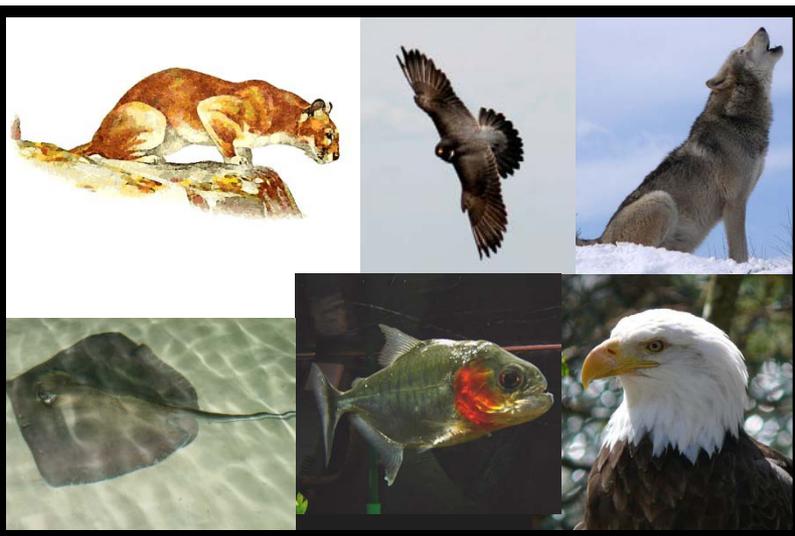
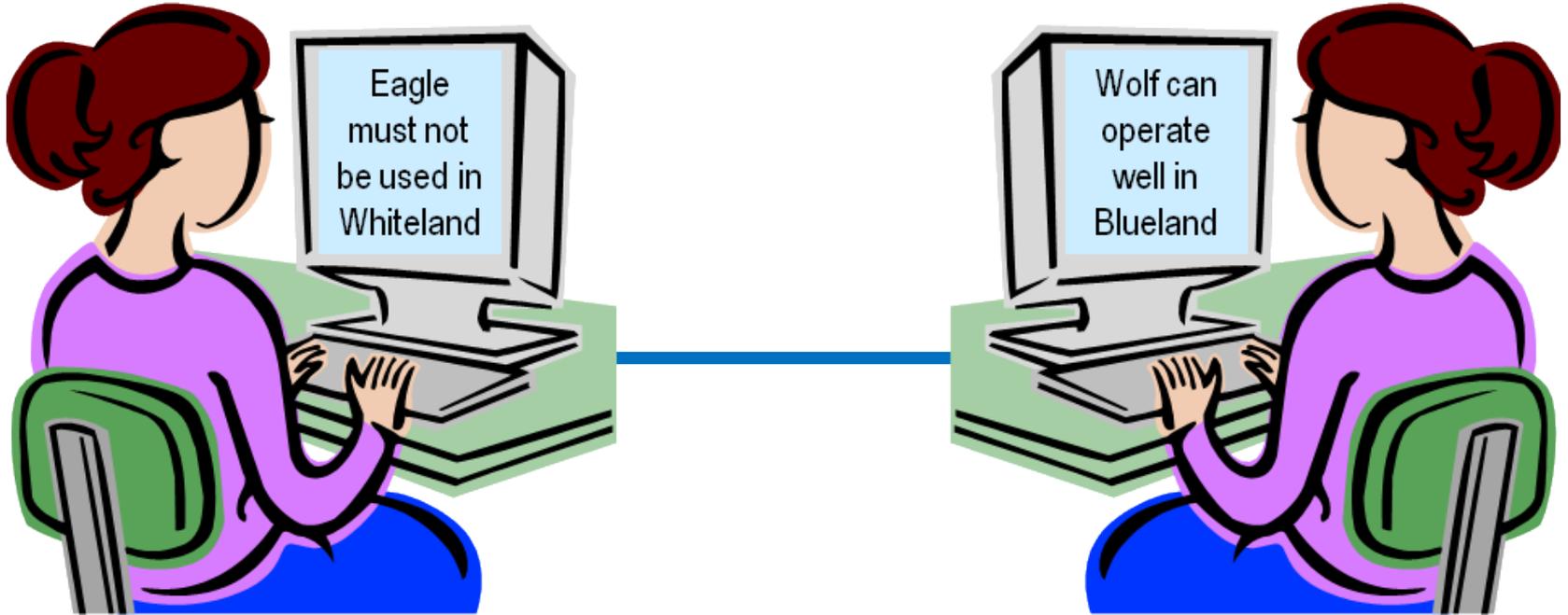
Hard information about target coordinates is black-or-white, but subtle information about command intent and human factors is in shades of grey.

Subtle information can be “attenuated” by being only partially understood, e.g. Lee at Gettysburg (1 July 1863): “seize that hill south of town if practicable”



Photo by Joshua Sherurcij

Future work: investigating this with a text-based problem



We have developed experimental & chat tools for this

FACT SUBSET #1:

Puma should, if possible, be used in Scarlet City

Falcon is not ideally suited to conditions in Orangeland

Stingray can operate well in Blueland

Wolf can operate well in Blueland

Puma is assigned to

Orangeland ▼

Please make your selection and click 'Go'

Go

This chat panel is for Alice to communicate with Bob

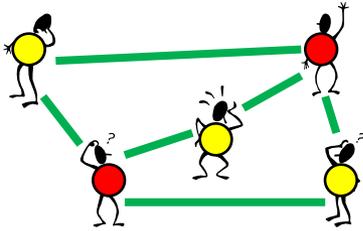
WELCOME! Mon Jan 17 18:35:11 EST 2011

Alice: Hello (18:35:11)

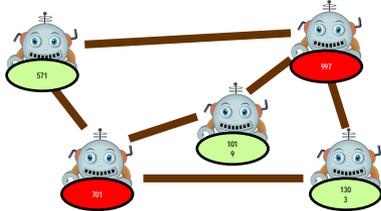
Summary



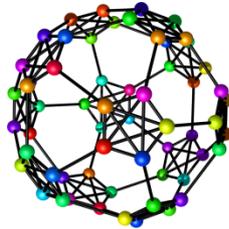
Human synchronisation experiments with ELICIT and ...



colouring suggest a linear distance/time relationship.



Our "factoring" simulation confirms this ...



but the Kuramoto model doesn't.



Future experiments are planned.