INFO1111
IT Computing 1A Professionalism

Week 6 – Systems Thinking and Complexity

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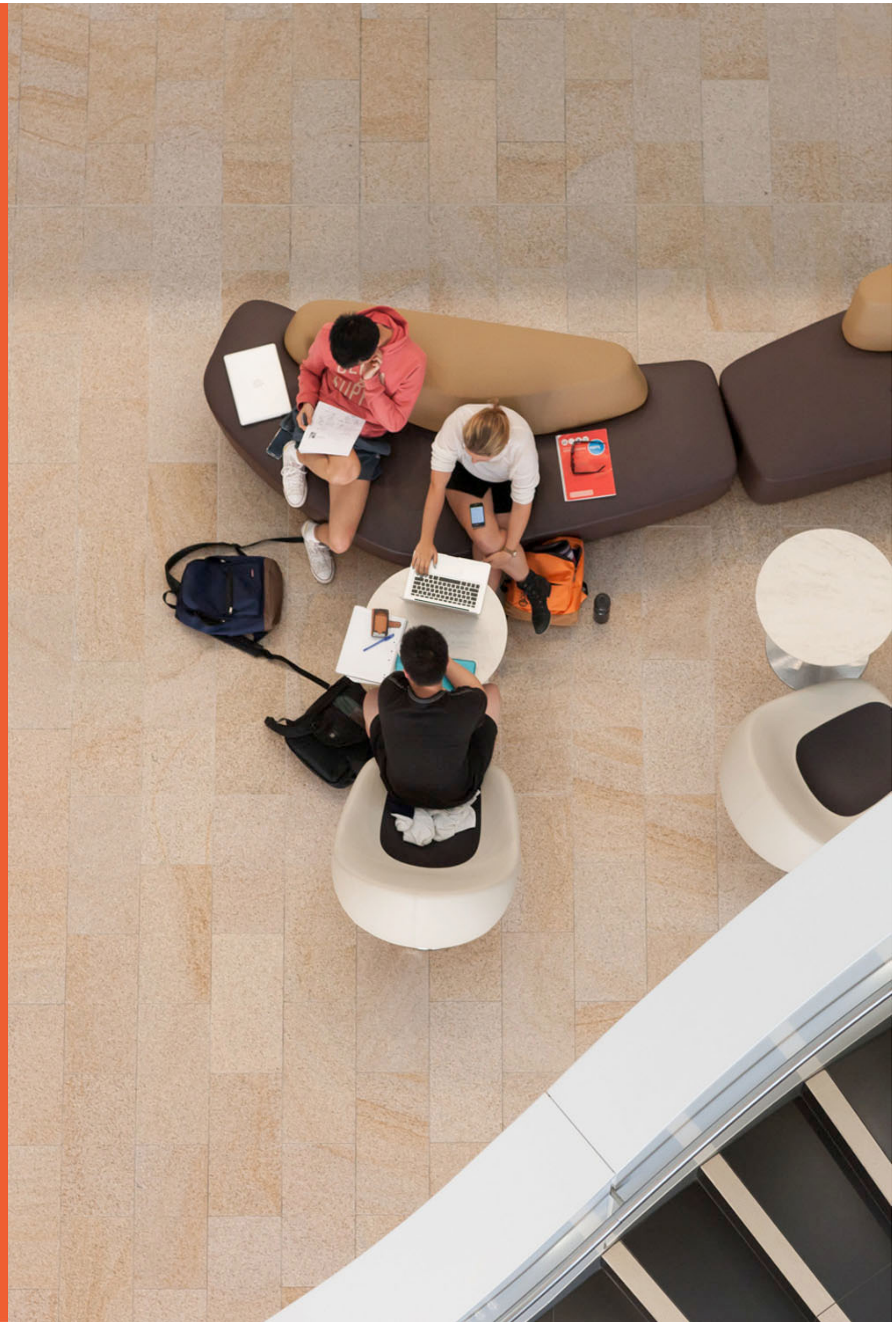
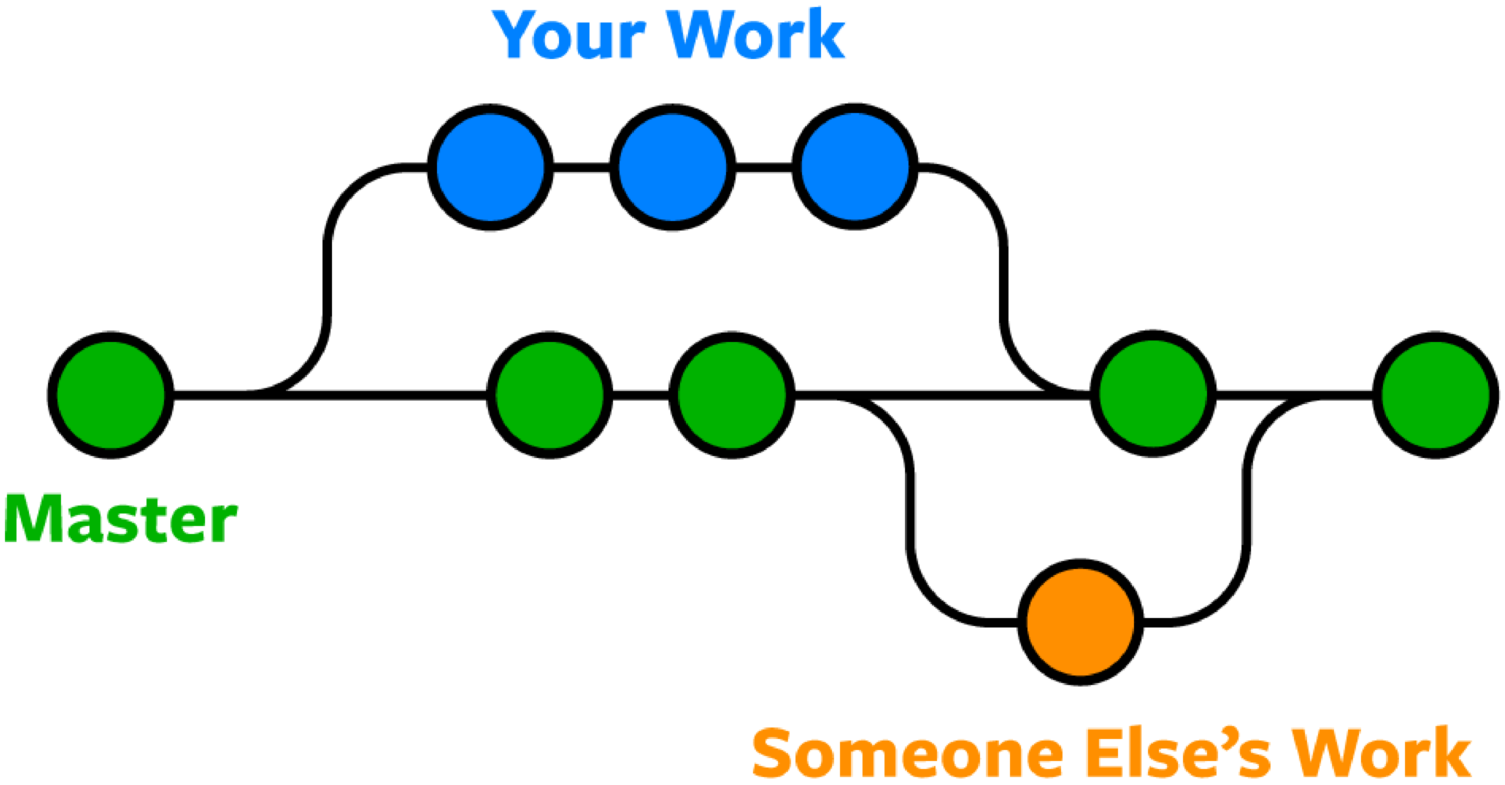
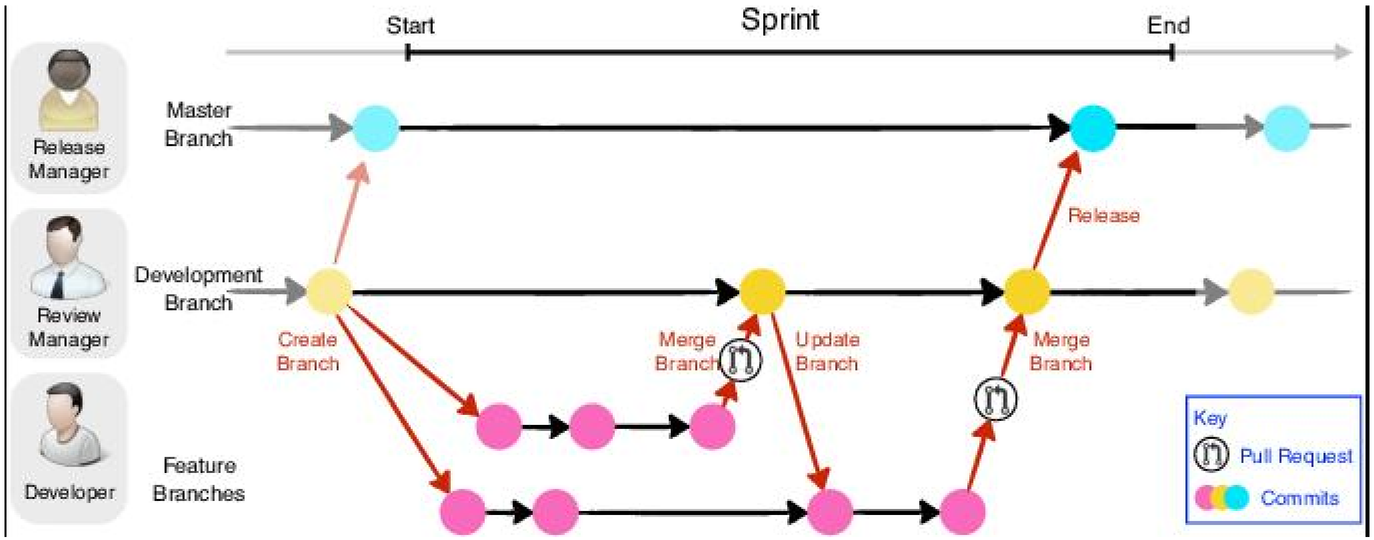
THE UNIVERSITY OF SYDNEY



From Week 5



From Week 5: A Process Model



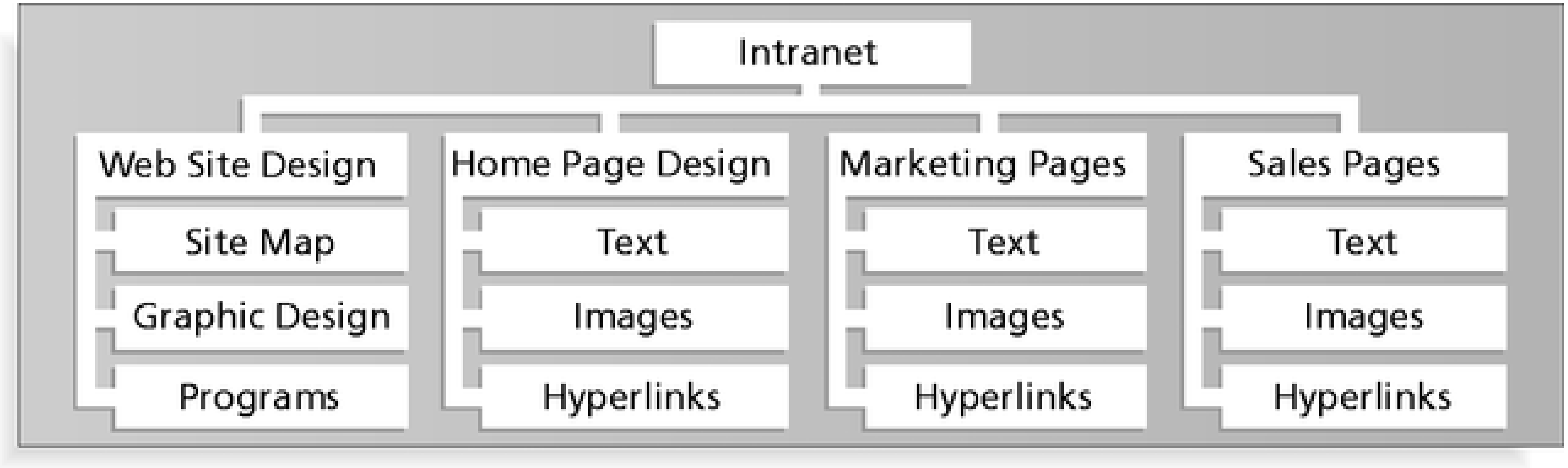
Creating the Work Breakdown Structure (WBS): for Software Construct Project

– A **WBS** is a deliverable-oriented grouping of the work involved in a project that defines the total scope of the project.

– A WBS is a foundation document that provides the basis for planning and managing project schedules, costs, resources, and changes.

– **Decomposition** is subdividing project deliverables into smaller pieces.

Sample Web Development WBS Organised by Product / Functions / …

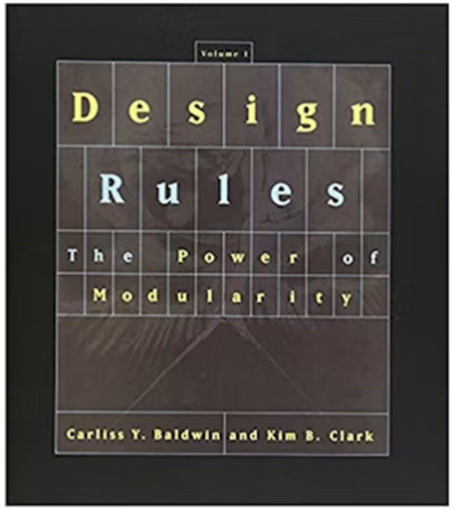


Approaches to Developing WBSs

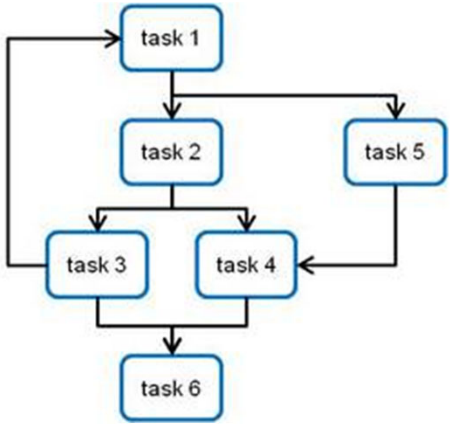
– **Analogy approach**: Review WBSs of similar software projects and tailor to your development project.
– **Top-down approach**: Start with the largest items of the project and break them down.
– **Bottom-up approach**: Start with the specific tasks and roll them up.
– **Mind-mapping approach**: Write tasks in a non-linear, branching format and then create the WBS structure.

Complex Systems Concepts for Systems Design adopted from Carliss Y Baldwin (2006)

- Large, Complex, evolving designs are fact of modern lift, we need "design architectures" –
  - "description of the entities in a system and their relationships"
  - Way of assigning work
- Design Architecture and Strategy
  - How can you create and capture value in a large, complex evolving set of designs?



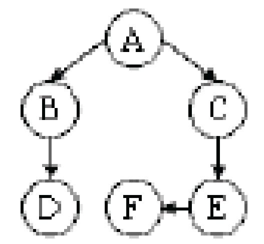
	task 1	task 2	task 3	task 4	task 5	task 6
task 1		X			X	
task 2			X	X		
task 3	X					X
task 4						X
task 5				X		
task 6						



The Design Precedence Matrix

Black, T. A., C. H. Fine, E. M. Sachs. 1990. A method for systems design using precedence relationships: An application to automotive brake systems. Working Paper 3208, Sloan School of Management, Massachusetts Institute of Technology, Cambridge, MA.

Figure 3: Example System in Graphical and DSM Form



	A	B	C	D	E	F
A	0	1	1	0	0	0
B	0	0	0	1	0	0
C	0	0	0	0	1	0
D	0	0	0	0	0	0
E	0	0	0	0	0	1
F	0	0	0	0	0	0

Source: Rivkin and Siggelkow (2007), Pattern Interactions in Complex Systems: Implication for Exploration, Management Science, 53(7), pp. 1068-1085. (Based on Stuart Kauffman NK Landscape)

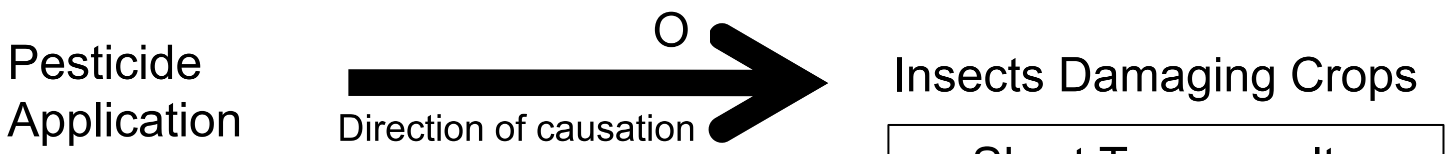
The Design Precedence Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1 CUSTOMER REQUMNTS	X												
2 WHEEL TORQUE		X		X									
3 PEDAL MECH. ADVANT.	X		X	X	X			X		X			X
4 SYSTEM LEVEL PARAM'S	X			X									
5 ROTOR DIAMETER	X	X	X	X	X		X	X		X	X		X
6 ABS MODULATOR DISPL.						X			X				
7 LINING COEFF. - FRT.			X	X	X		X	X		X			X
8 PISTON - REAR SIZE		X		X				X		X			
9 CALIPER COMPLIANCE			X	X					X	X			X
10 PISTON - FRONT SIZE		X		X				X		X			
11 LINING COEFF - REAR			X	X	X			X		X	X		X
12 BOOSTER - MAX STROKE												X	X
13 BOOSTER REACT. RATIO		X	X	X	X		X	X		X	X		X

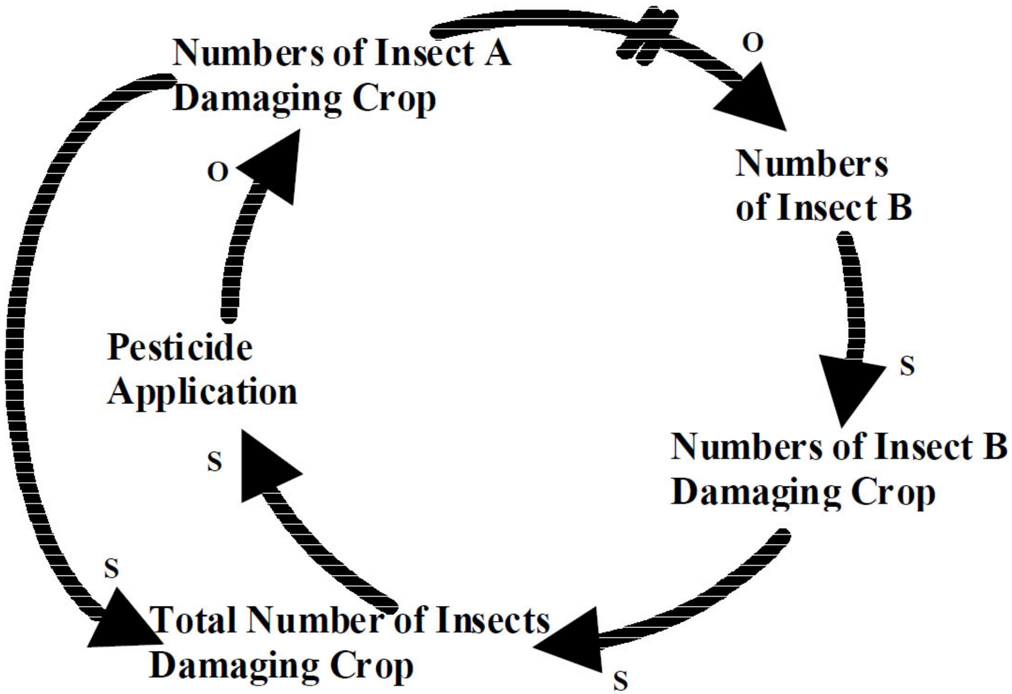
Figure 1

Complex Systems Thinking

Case: Pesticide Example (by Daniel Aronson)



Short Term results

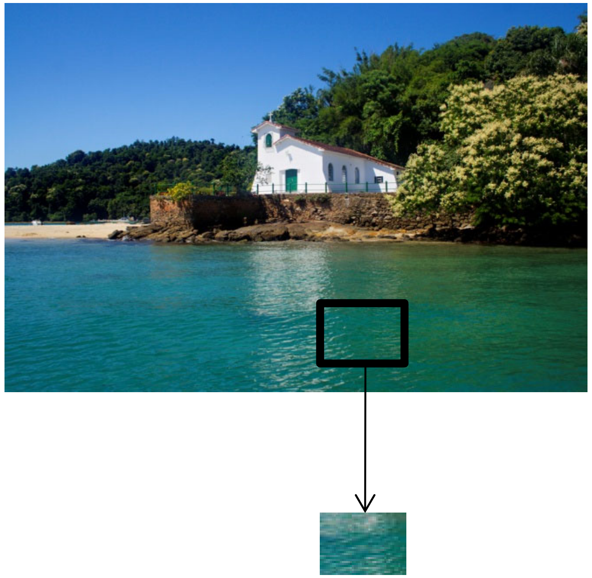


Long Term results

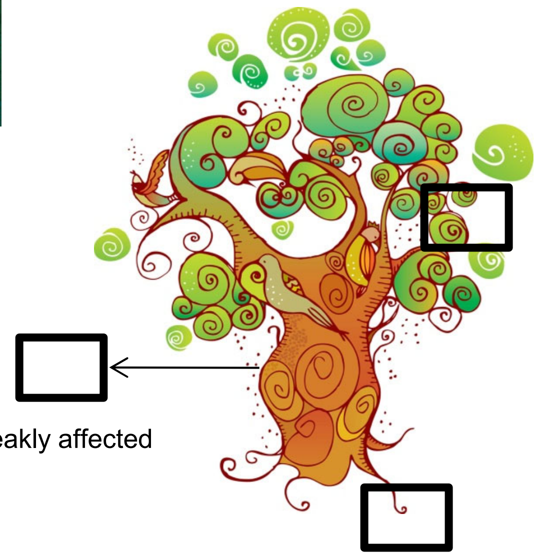
Predator and Prey Simulator

DEMO

Fundamental: Parts, Wholes and Relationships



Internal Properties unchanged



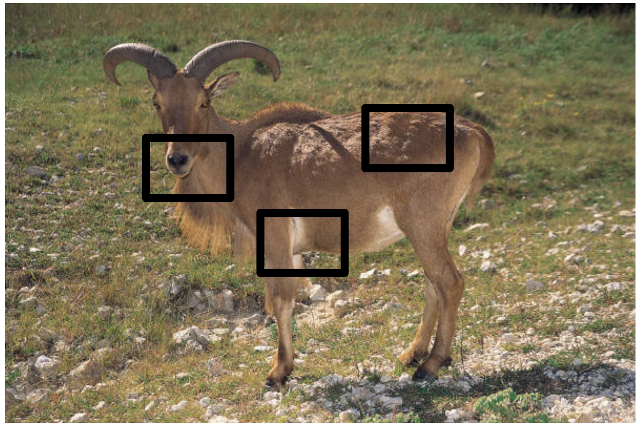
Strongly affected

Weakly affected

Strongly affected

Strongly affected

Strongly affected



Strongly affected

Key Systems Principles (Simplified)

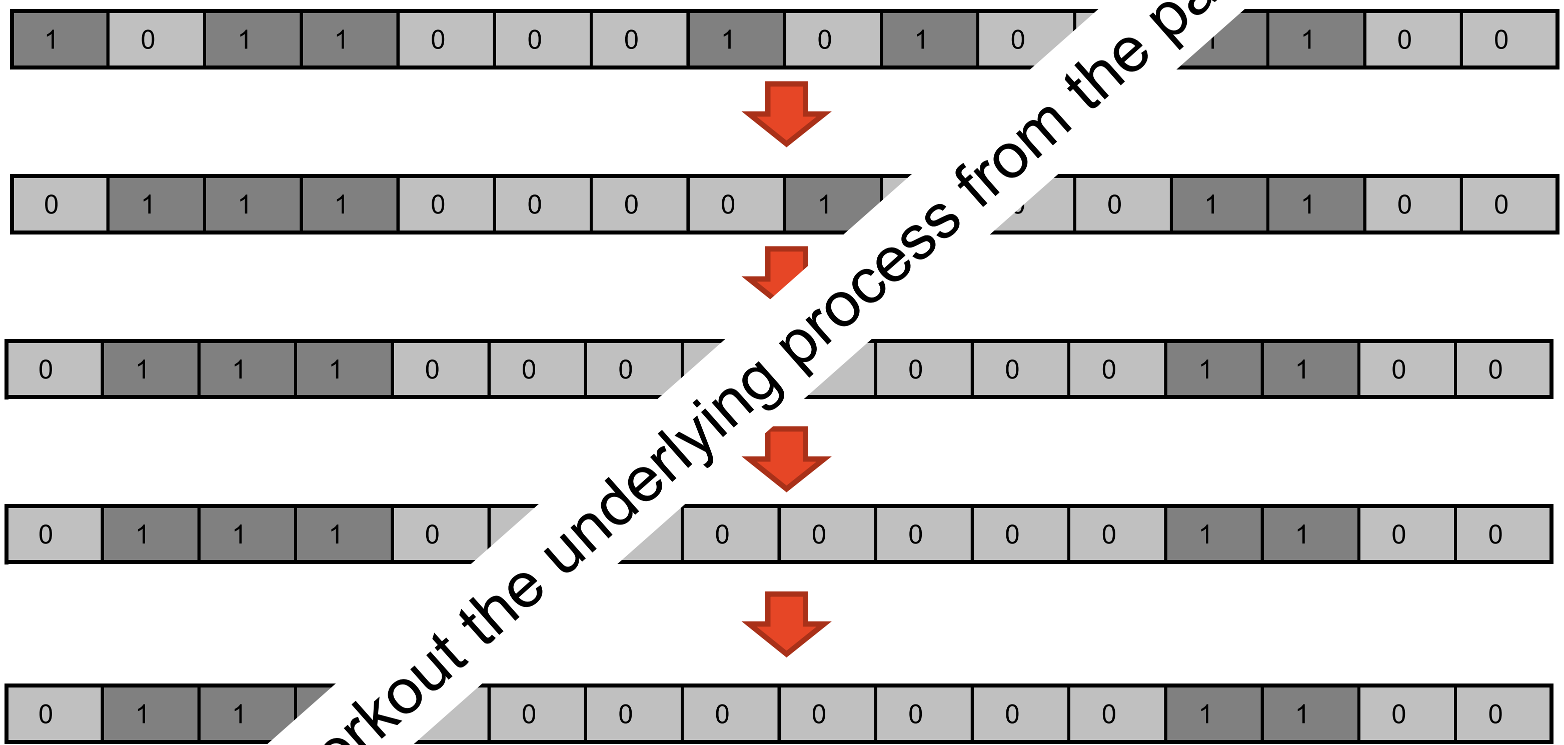
- Openness:
  - System behaviour can only be understood in relation to the external environment
  - Distinction between the system and the environment – systems boundary
  - ***Controllable and uncontrollable variables***
- Purposefulness
  - Value-guided systems
  - Role of understanding (why actors do what they do)
  - Reaction- response- action
  - Active Role of Choice
  - ***Adaptiveness***
- Emergent Property
  - Property of the whole that cannot be deduced from the properties of the parts
  - ***Emergent properties*** as the product of complex interactions among several elements.
- Multidimensionality
  - Plurality of structures and processes.
  - Seemingly opposing tendencies not only co-exist to form a complementary relationship
  - ***Multiple interacting dimensions***
- Counter-intuitiveness
  - Actions intended to produce certain outcomes may generate opposite results.
  - ***Inflection Points***

Systems Approach & Systems Theory

- ***The systems approach or systems thinking*** is a method of analysing or thinking about complex systems from the perspective of the total system, the goals of the overall system, the individual components, and the inter-relationships and inter-dependencies between the components.

- ***Systems Theory***: the transdisciplinary study of the abstract organization of complex phenomena, independent of their substance, type, or spatial, or temporal scale of existence. It investigates both the principles common to all complex entities, and the (usually mathematical) models that can be used to represent them.

Class Exercise:
Dynamics of Complex Systems (Pattern Formation)



How to workout the underlying process from the patterns?

Source: Making Things Work: Solving Complex Problems in a Complex World (Bar-Yam 2004)

Start with different structures…

1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0

1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0

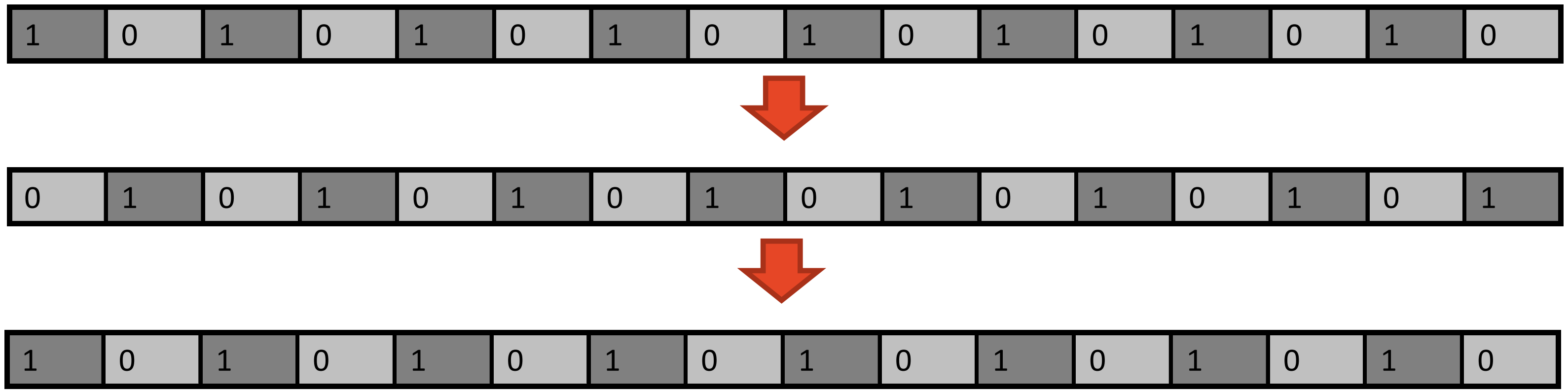
1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0

1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0

1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0

1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0

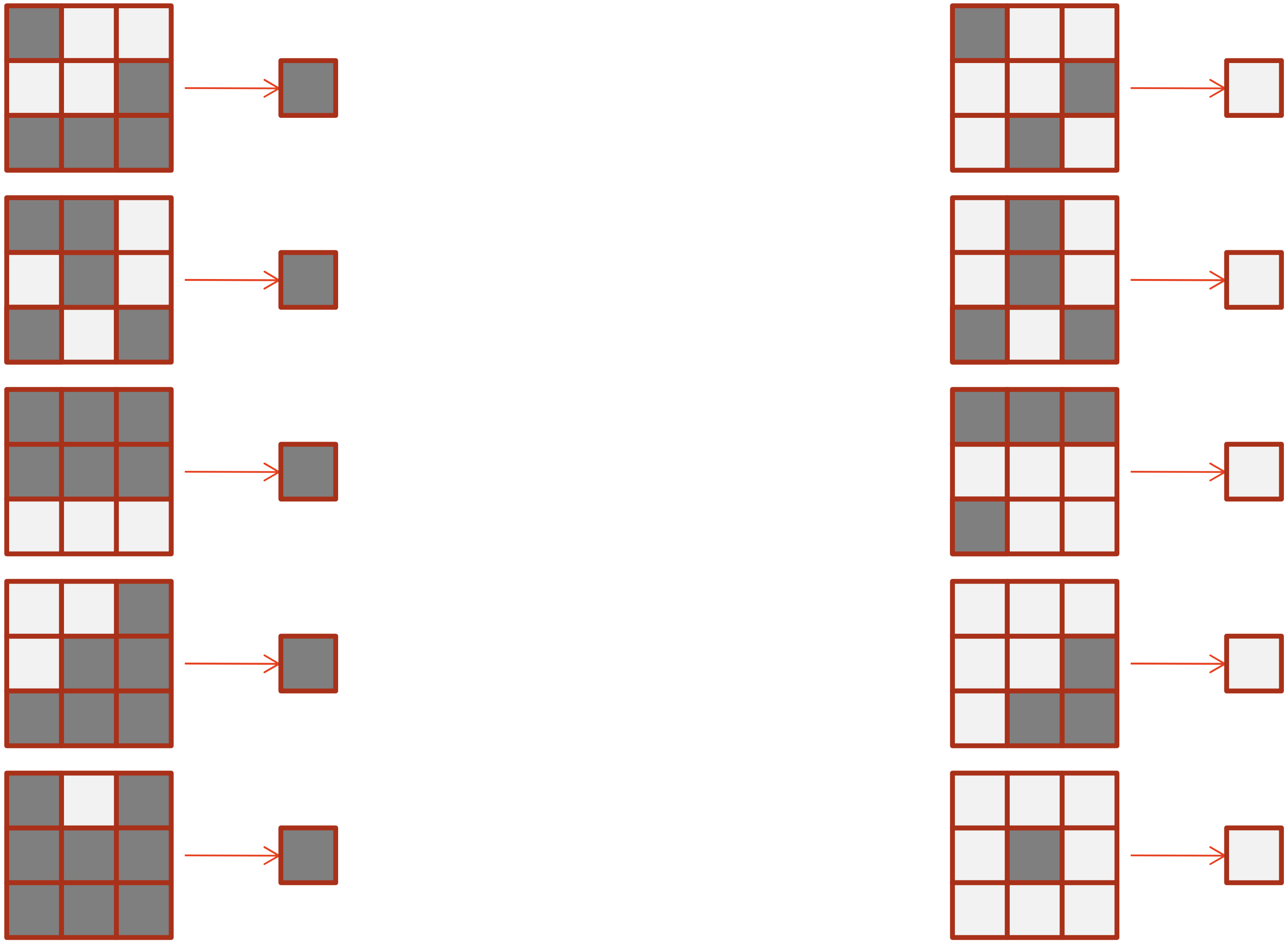
Another structure…



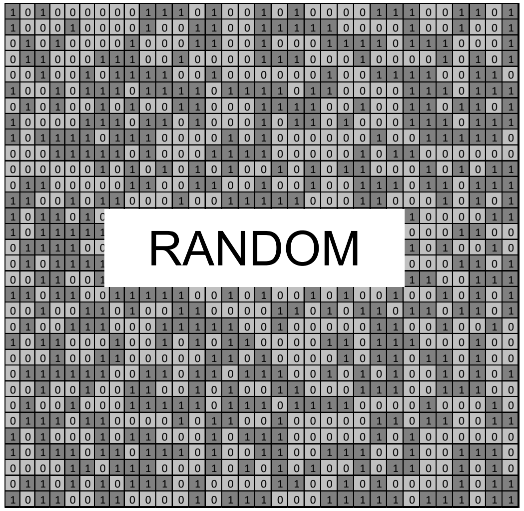
There are total of possible 2^n structures!!!

A Model of Panic

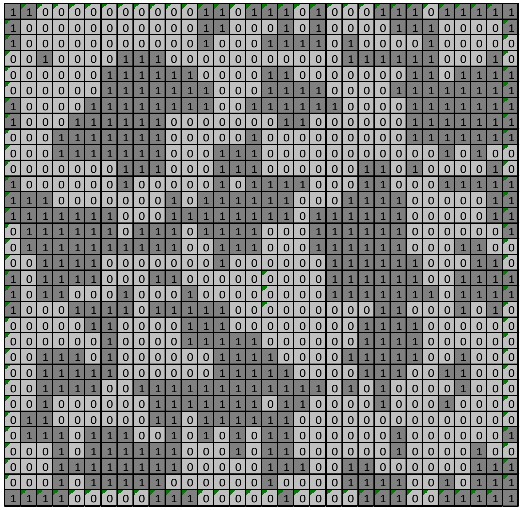
– A model of panic, based on local interactions. Lighter shades represent calm people; while darker shades represent panicky people. On the LHS, the person in the centre will panic; on the RHS, the person in the centre remain/become calm.



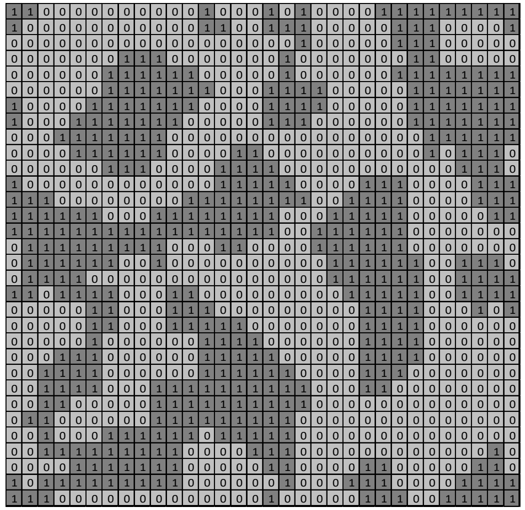
Model of crowded auditorium: N repetitions of the panic rule



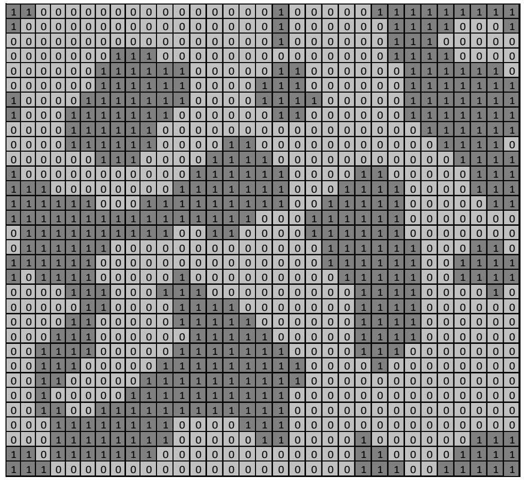
Step: 0 Number of 0s: 526 Number of 1s: 498



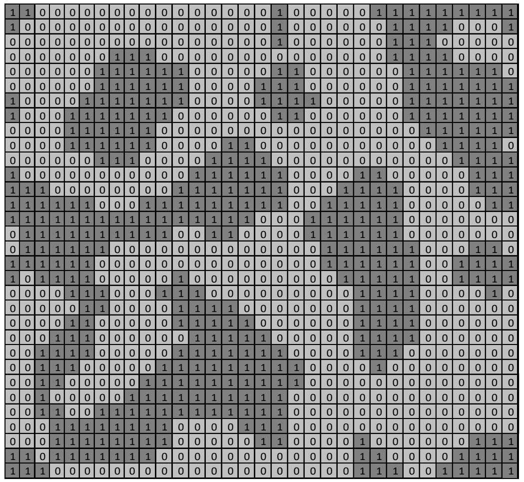
Step: 1 Number of 0s: 557 Number of 1s: 467



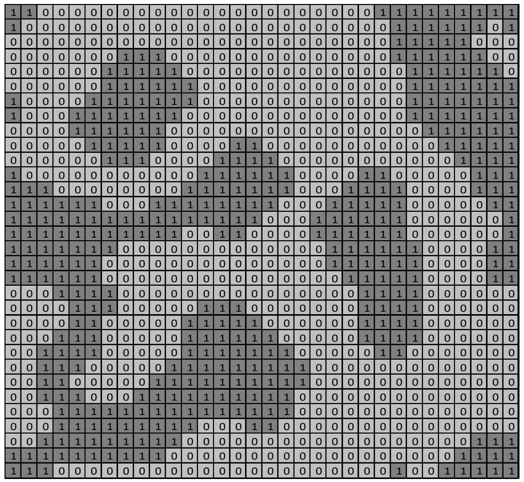
Step: 2 Number of 0s: 584 Number of 1s: 440



Step: 3 Number of 0s: 598 Number of 1s: 426



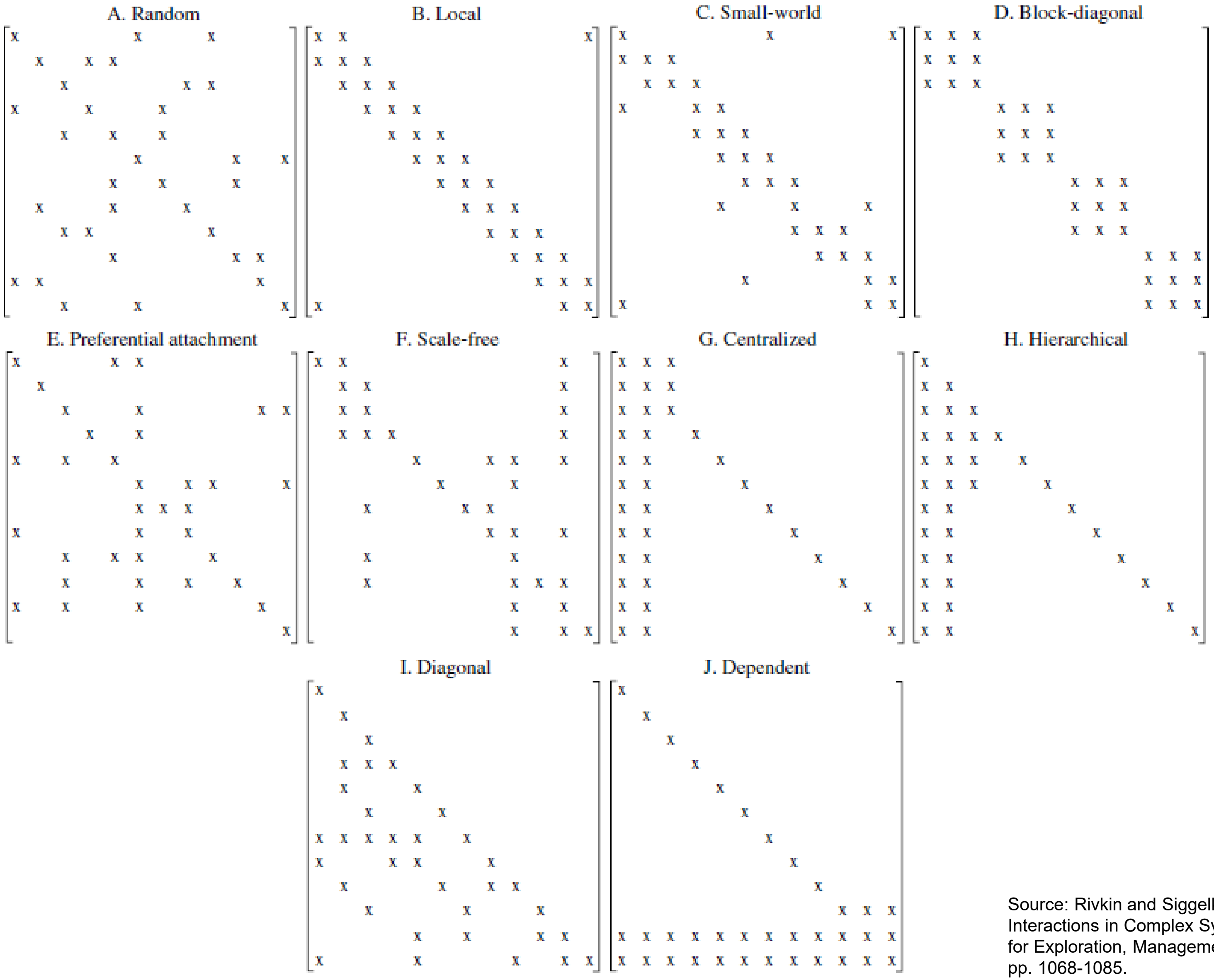
Step: 4 Number of 0s: 605 Number of 1s: 419



Step: 8 Number of 0s: 614 Number of 1s: 410

Start with different structures…

Figure 1 Different Types of Influence Matrices, All with the Same Number of Total Interactions ($N = 12$, $K = 2$, $N * (K+1) = 36$)



Source: Rivkin and Siggelkow (2007), Pattern Interactions in Complex Systems: Implication for Exploration, Management Science, 53(7), pp. 1068-1085.

Systems Design Thinking

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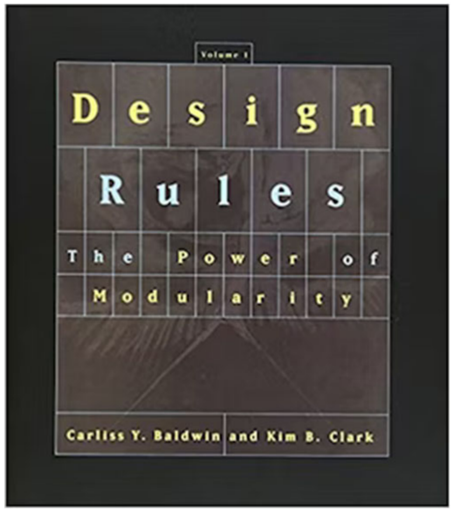
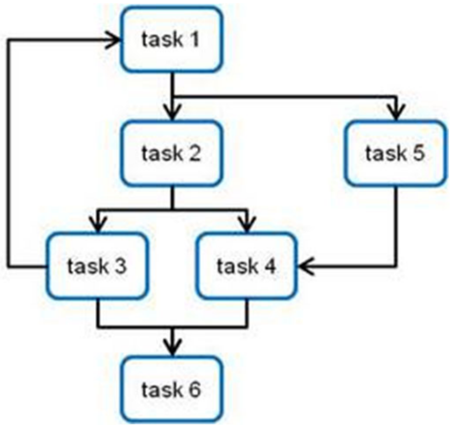


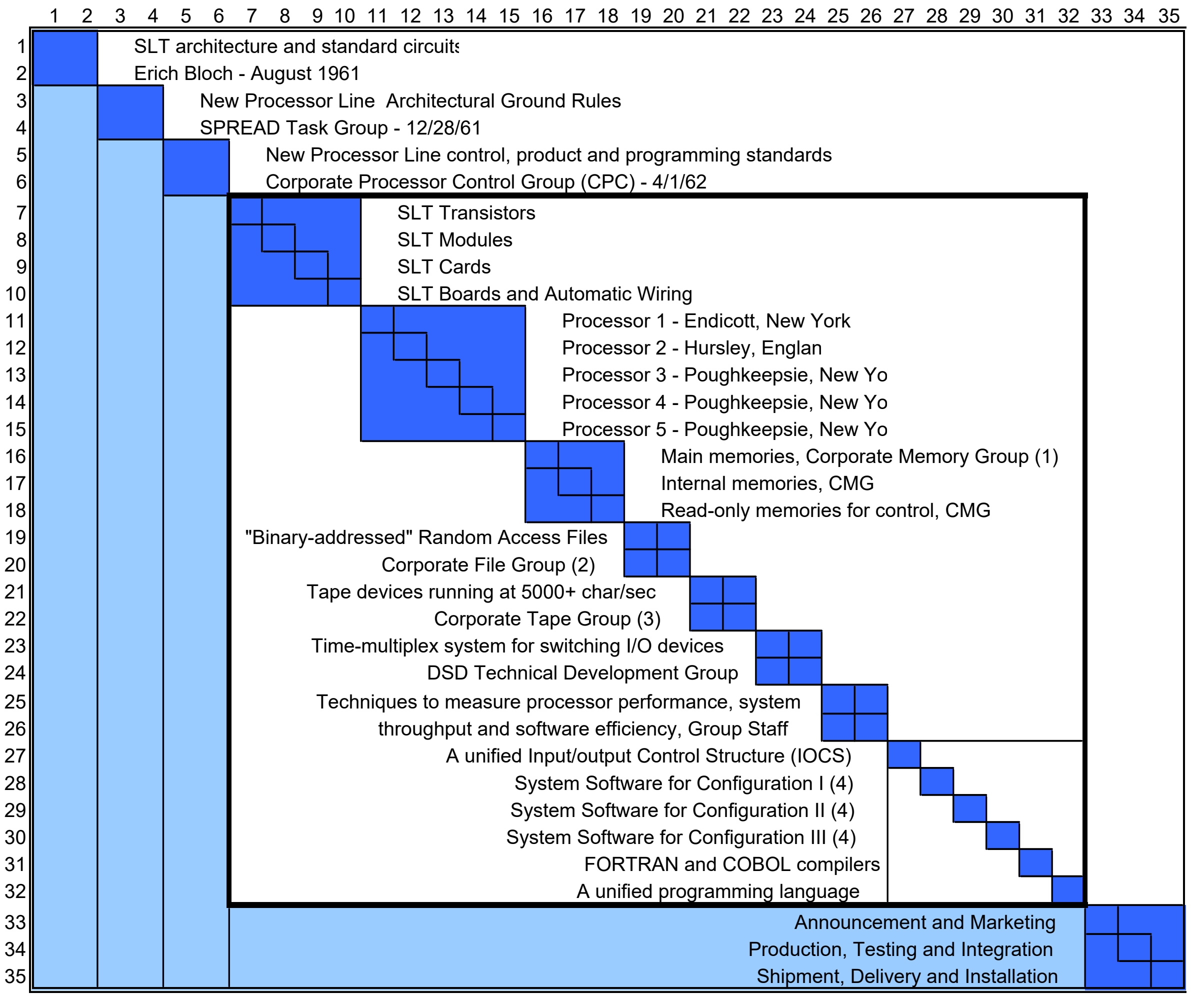
	task 1	task 2	task 3	task 4	task 5	task 6
task 1		X			X	
task 2			X	X		
task 3	X					X
task 4						X
task 5				X		
task 6						



The Concept of Modularity

- The degree to which a set of designs (or tasks) is partitioned into components, called modules, that are
- highly dependent within a module, nearly independent across modules
- A property of architecture, somewhat under the architect's control
- Modularity in computers (IBM System/360)
  - First modular computer design architecture (1962-1967)
  - Proof of concept in hardware and application software
  - Proof of option value in market response and product line evolution
  - System software was NOT modularizable

IBM in the 1906s wanted to be the sole source of all of System/360's Modules



Dependence Structure Matrix & Landscape Characterisation

Table 1 **Characteristics of Actual Design Structure Matrices and Activity Systems**

Example	N	$K^{\dagger}$
Design structure matrices		
Automobile brake system (Black et al.1990)	13	3.8
Kodak cartridge development process (Ulrich and Eppinger 2007)	14	2.5
Automobile climate control system (Pimmler and Eppinger 1994)	16	1.4
Automobile door (Dong 1999)	32	3.4
Automobile digital mock-up process for the layout for components in the engine compartment (Ulrich and Eppinger 2007)	50	3.5
Semiconductor development process (Osborne 1993)	60	6.5
Power plant design	72	6.8
Jet engine design (Mascoli 1999)	111	5.8
Activity systems		
Vanguard–1974 (Siggelkow 2002)	18	2.2
Vanguard–1977 (Siggelkow 2002)	24	2.8
Vanguard–1978 (Siggelkow 2002)	29	2.8
Vanguard–1991 (Siggelkow 2002)	41	2.9
Vanguard–1997 (Siggelkow 2002)	48	3.0
Liz Claiborne–1990 (Siggelkow 2001)	36	3.2
Liz Claiborne–1997 (Siggelkow 2001)	34	3.5
IKEA–1996 (Porter 1996)	20	3.4
Southwest Airlines–1996 (Porter 1996)	18	3.4
Vanguard–1996 (Porter 1996)	25	3.4

†The value of K is computed by dividing the number of off-diagonal interaction effects by N.

Figure 2: The Directory Structure and Architectural View of Linux version v0.01.

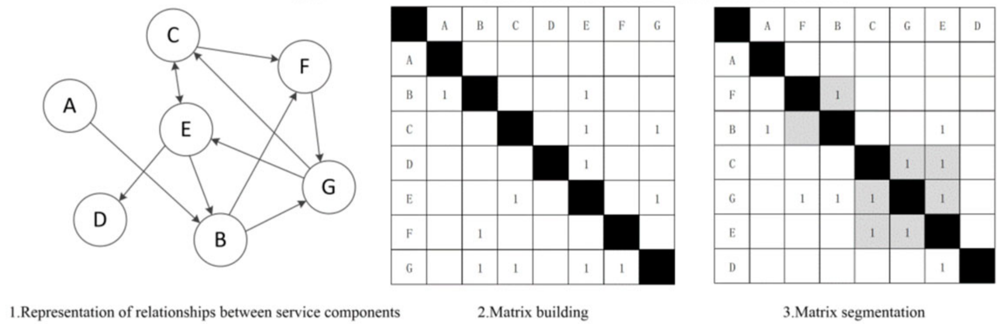
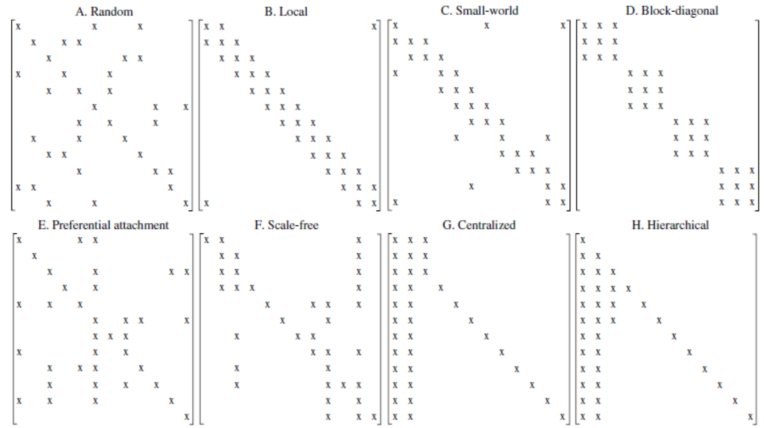
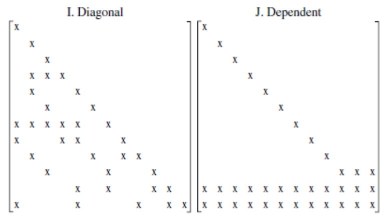
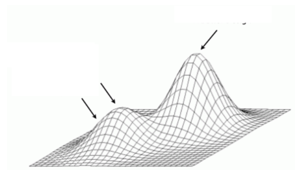


Figure 1 **Different Types of Influence Matrices, All with the Same Number of Total Interactions** ($N = 12$, $K = 2$, $N * (K + 1) = 36$)





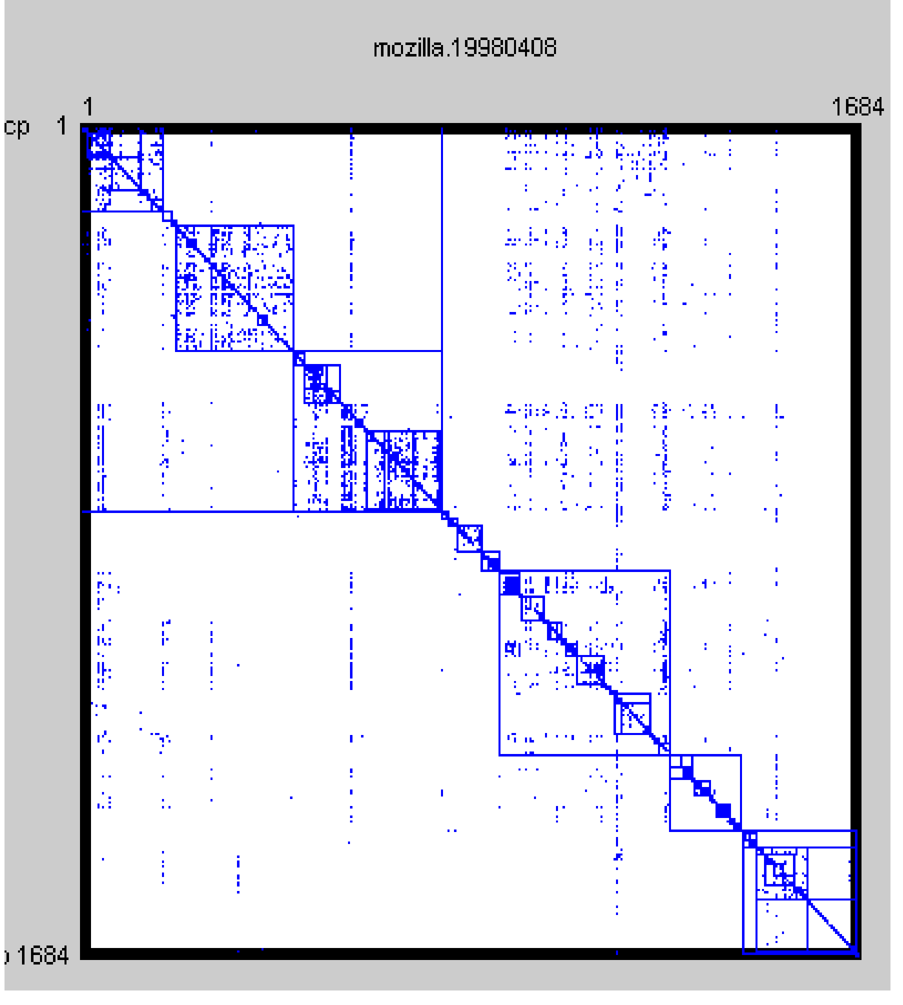


Source: Rivkin and Siggelkow (2007), Pattern Interactions in Complex Systems: Implication for Exploration, Management Science, 53(7), pp. 1068-1085. (Based on Stuart Kauffman NK Landscape)

Measuring modularity

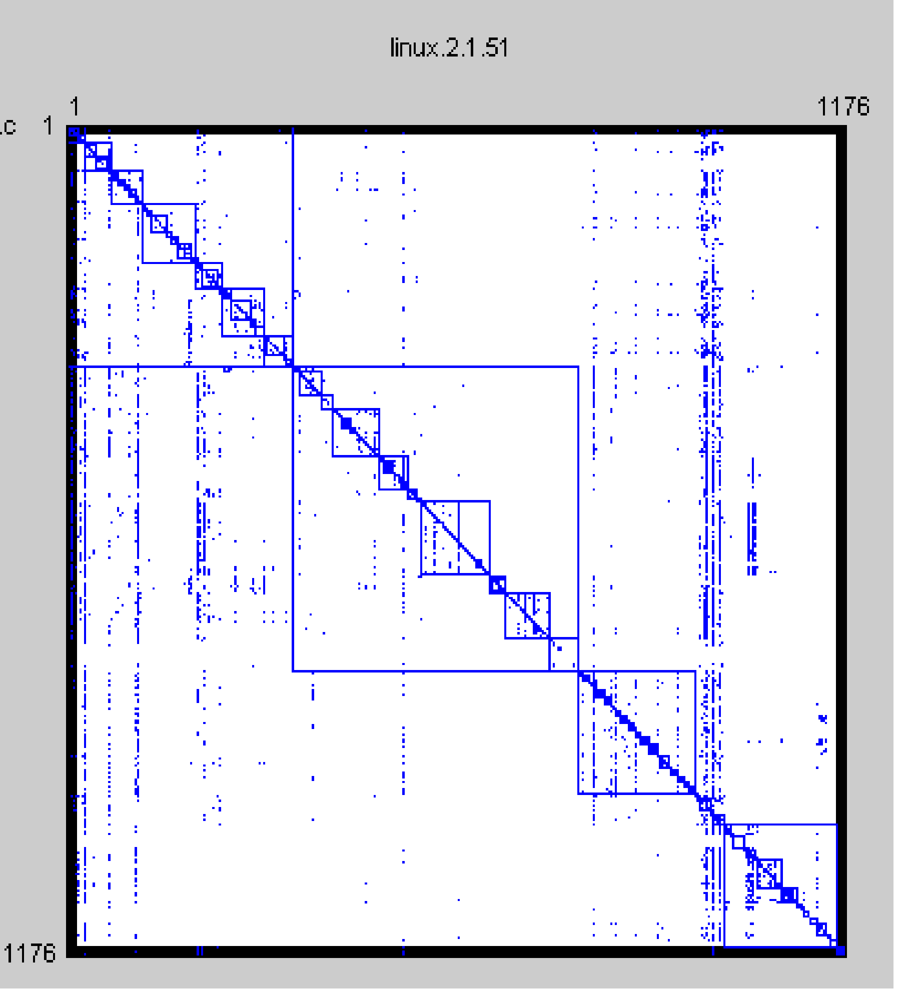
Comparison of different software systems with DSM tools

Mozilla just after becoming open source



Coord. Cost = 30,537,703
Change Cost = 17.35%

Linux of similar size



Coord. Cost = 15,814,993
Change Cost = 6.65%

Source: Alan MacCormack, Johh Rusnak and Carliss Baldwin, 2006

The *Systems thinking* approach incorporates several tenets:

- Interdependence of objects and their attributes - independent elements can never constitute a system
- Holism - emergent properties not possible to detect by analysis should be possible to define by a holistic approach
- Goal seeking - systemic interaction must result in some goal or final state
- Inputs and Outputs - in a closed system inputs are determined once and constant; in an open system additional inputs are admitted from the environment
- Transformation of inputs into outputs - this is the process by which the goals are obtained
- Entropy - the amount of disorder or randomness present in any system
- Regulation - a method of feedback is necessary for the system to operate predictably
- Hierarchy - complex wholes are made up of smaller subsystems
- Differentiation - specialized units perform specialized functions
- Equifinality - alternative ways of attaining the same objectives (convergence)
- Multifinality - attaining alternative objectives from the same inputs (divergence)

Source: http://en.wikipedia.org/wiki/Systems_thinking