Structural Modeling Framework

Joseph J Simpson
Mary J Simpson

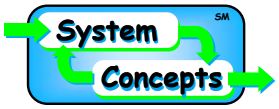
Overview

- **Introduction – set context**
- **Structural Modeling - components**
  - Basic structural modeling
  - Structural integration modeling
  - Interpretive structural modeling
- **Example Application - ‘north-of’**
  - Ordering cities
  - Typical operations
- **Summary**

Structural Modeling Introduction

- **Used to reduce complexity – main objective**
- **Provides structured analysis processes**
  - Initial conditions: Unknown or poorly defined systems
  - Process integrates rational inquiry and logic
  - How to test? What can be tested?
- **Employs unique Boolean operations**
  - Boolean ordering operators (added > and <)
  - Boolean matrix operations supported
- **Dynamic approach needed to integrate rational inquiry and logic**

Structural Modeling Components



Basic Structural Models (BSM)

Abstract concepts that carry no empirical or substantive information.

Properties known, methods permit extensive manipulation, structural insights

Mathematicians with necessary mathematical knowledge in logic, matrix theory, theory of graphs)

"in proper correspondence"

Interpretive Structural Models (ISM)

Developed to organize/understand empirical, substantive knowledge about complex systems/issues

Properties not necessarily known

Domain experts engaged in day-to-day interactions with complexity

Use computer for "**logistical tyranny**" associated with extensive manipulation of ideas [Warfield, 1974]

Structural Integration Modeling (SIM)

Pair appropriate organizing relationship with specific sets of mathematical relations, and their properties and attributes.

Work systematically to establish relations among many elements in the form of an interpretive structural model.

Use abstract relation type (ART) forms (prose descriptions, graphic representations, executable computer codes) to encode and communicate information

Systems scientist / systems engineer develop and test

Basic Structural Modeling

- **Centered in mathematical models**
- **Domain of mathematicians**
  - Matrix theory
  - Graph theory
  - Application of logic and reasoning
- **Provides a set of**
  - Well known tools
  - Robust operations
- **Carries no empirical or substantive information**

Interpretive Structural Modeling

- **Centered in day-to-day issues and data**
- **Domain of operations experts**
  - Contains empirical knowledge
  - Addresses complex systems and issues
  - Properties not necessarily known
- **Provides a set of**
  - Organizational principles
  - Well defined solution processes
- **Focuses on gathering empirical or substantive information**

Structural Integration Modeling

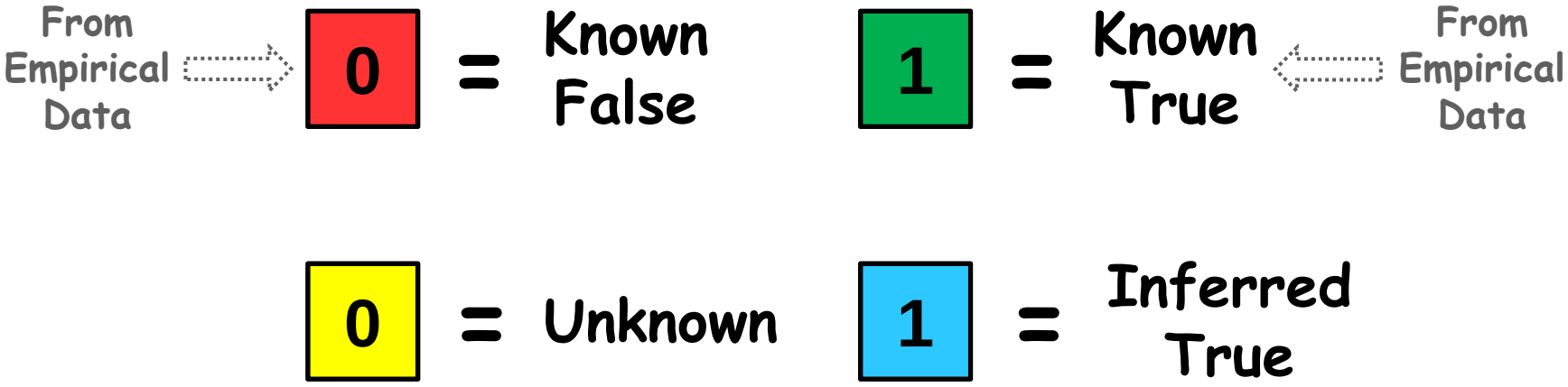
- **Focuses on model correspondence**
- **Domain of systems engineer/scientist**
  - Aligns mathematical tools with issues
  - Pairs organizing relationship and relations
  - Creates specific solution approach
- **Provides a set of**
  - Established methods and techniques
  - Language transforms
- **Aligns mathematics and logic to solve a specific problem - identifies pattern or structure**

Logical Datatypes?

Decimal Operations	Boolean Operations
0 + 0 = 0	0 + 0 = 0
0 + 1 = 1	0 + 1 = 1
1 + 0 = 1	1 + 0 = 1
1 + 1 = 2	1 + 1 = 1
0 x 0 = 0	0 x 0 = 0
0 x 1 = 0	0 x 1 = 0
1 x 0 = 0	1 x 0 = 0
1 x 1 = 1	1 x 1 = 1
0 < 1	0 < 1
1 > 0	1 > 0

Warfield Augmented Boolean Algebra

Logical Datatype Semantics



Simpson Augmented Boolean Algebra

Boole - *An Investigation of The Laws of Thought*

0 = Nothing 1 = Universe

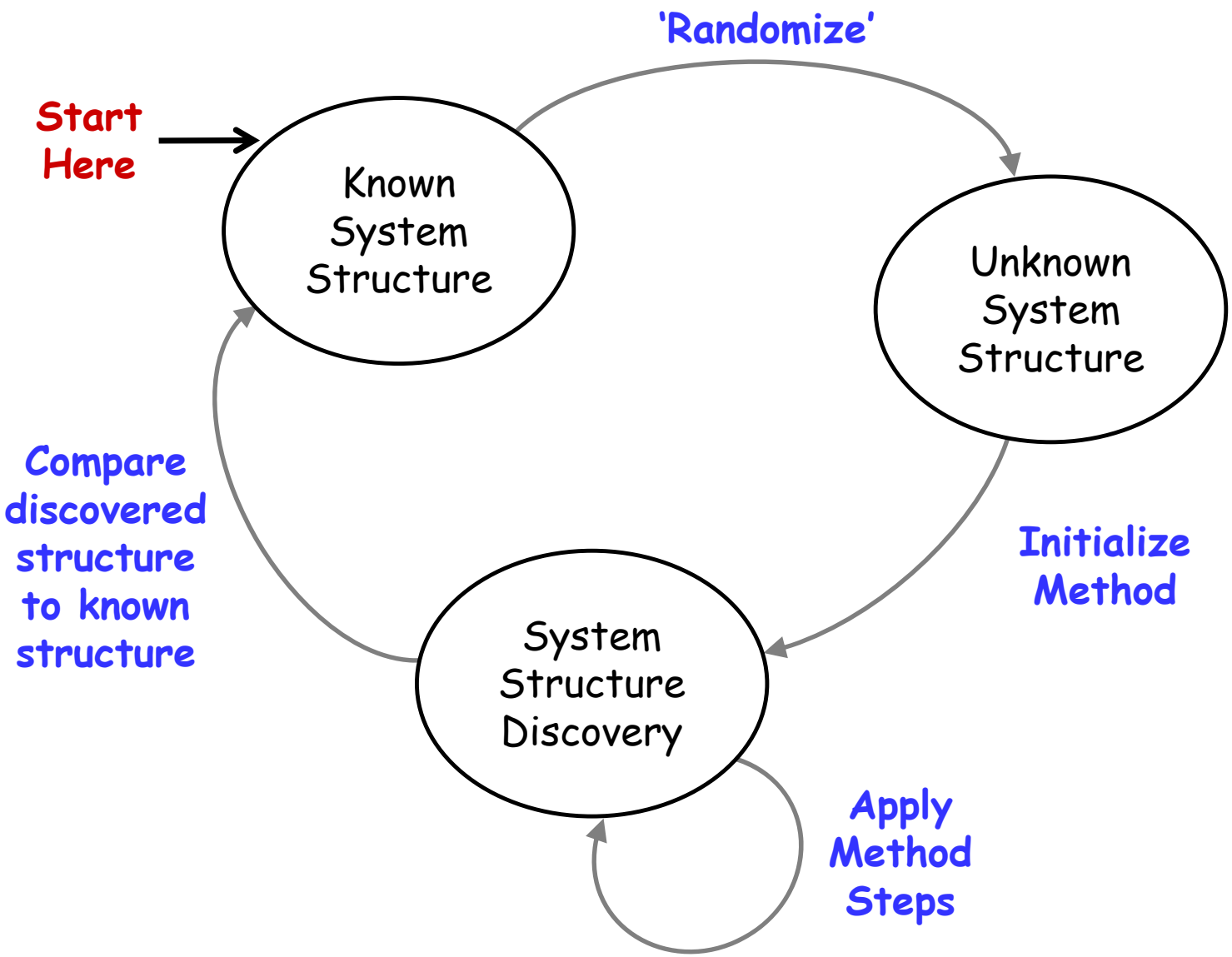
See p. 48

19 Cities - Example Problem Context

- Cities are known to exist
- Global structuring relationship - ‘north-of’
- Objective is to properly structure cities using lowest cost approach
- Empirical data collection uses resources
- Inferred data may be calculated at no cost

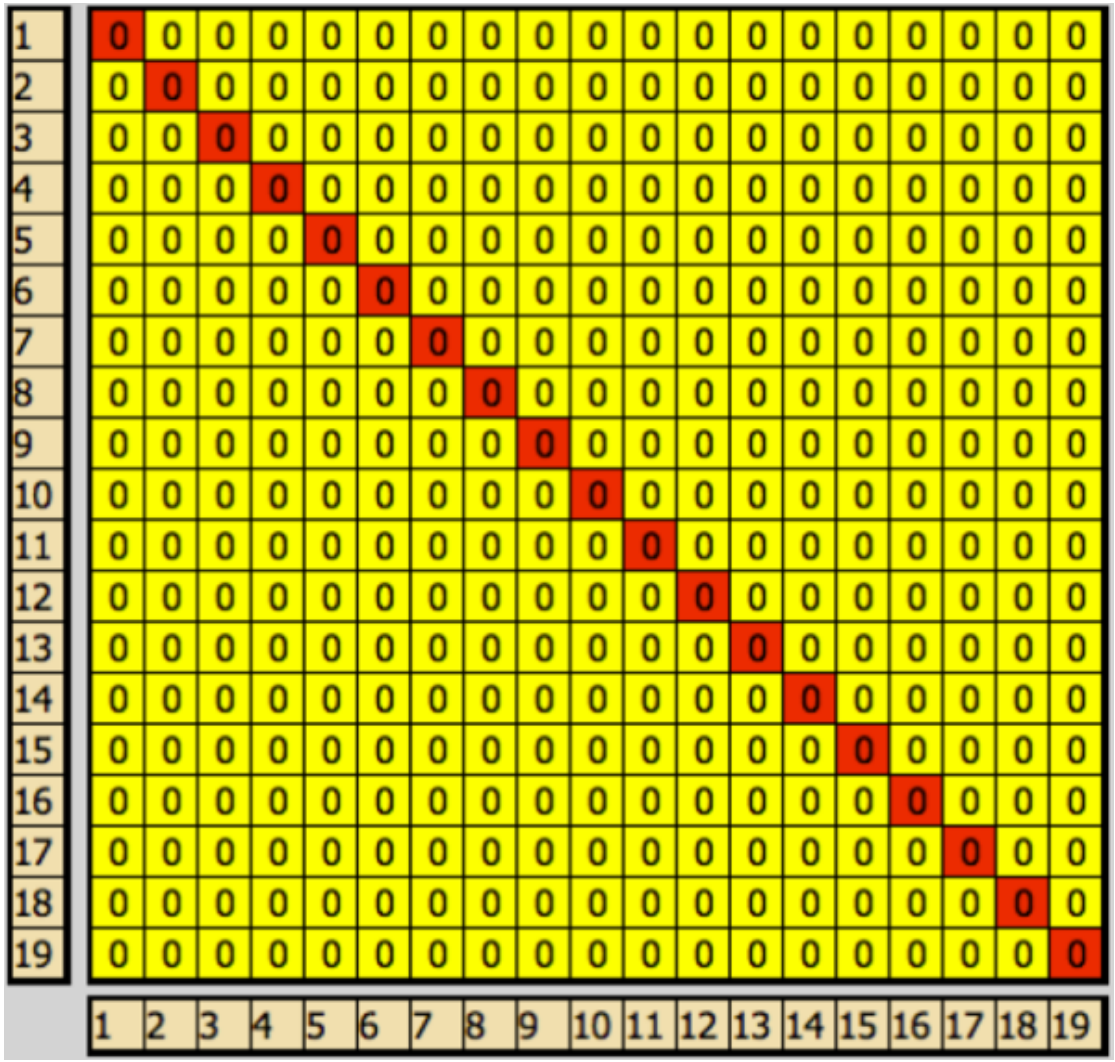
BSM	SIM	ISM
Math, Logic Properties **Asymmetric Irreflexive Transitive**	Solution Design **Uses logic to minimize data collection costs**	Problem Structuring **Empirical data collection**

Method Test, Validation and Verification



Example – Ordering Cities

Initial configuration



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18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Red background means ***'known false'***

Yellow background means ***'unknown'***

First Set Of Data

Configuration after 1st Set of Data Input

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4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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14	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
19	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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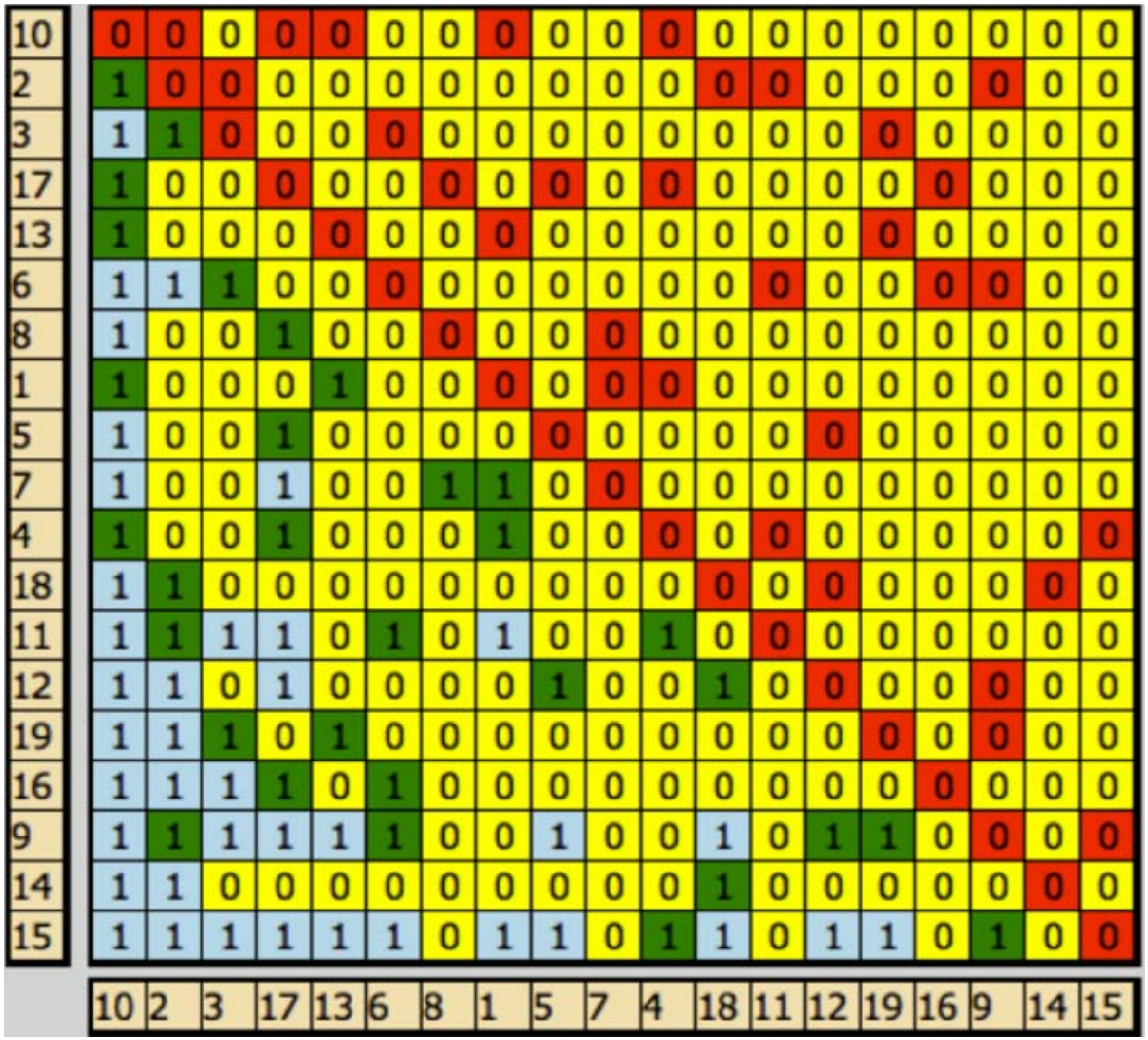
Blue background means ***'inferred true'***

Green background means ***'known true'***

More Data Collected

More Data



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6	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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14	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
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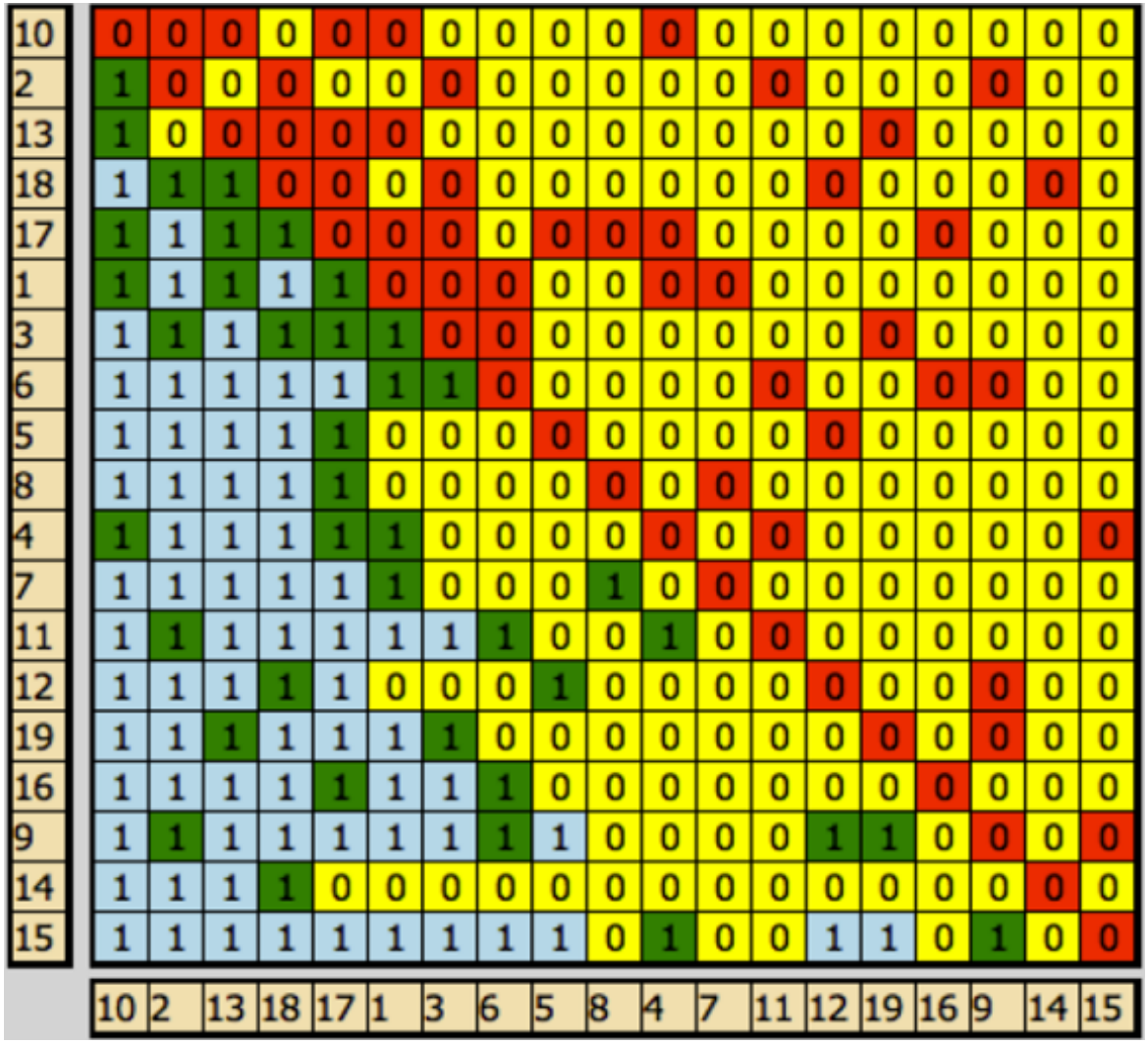
After More Data Is Collected

And more Data



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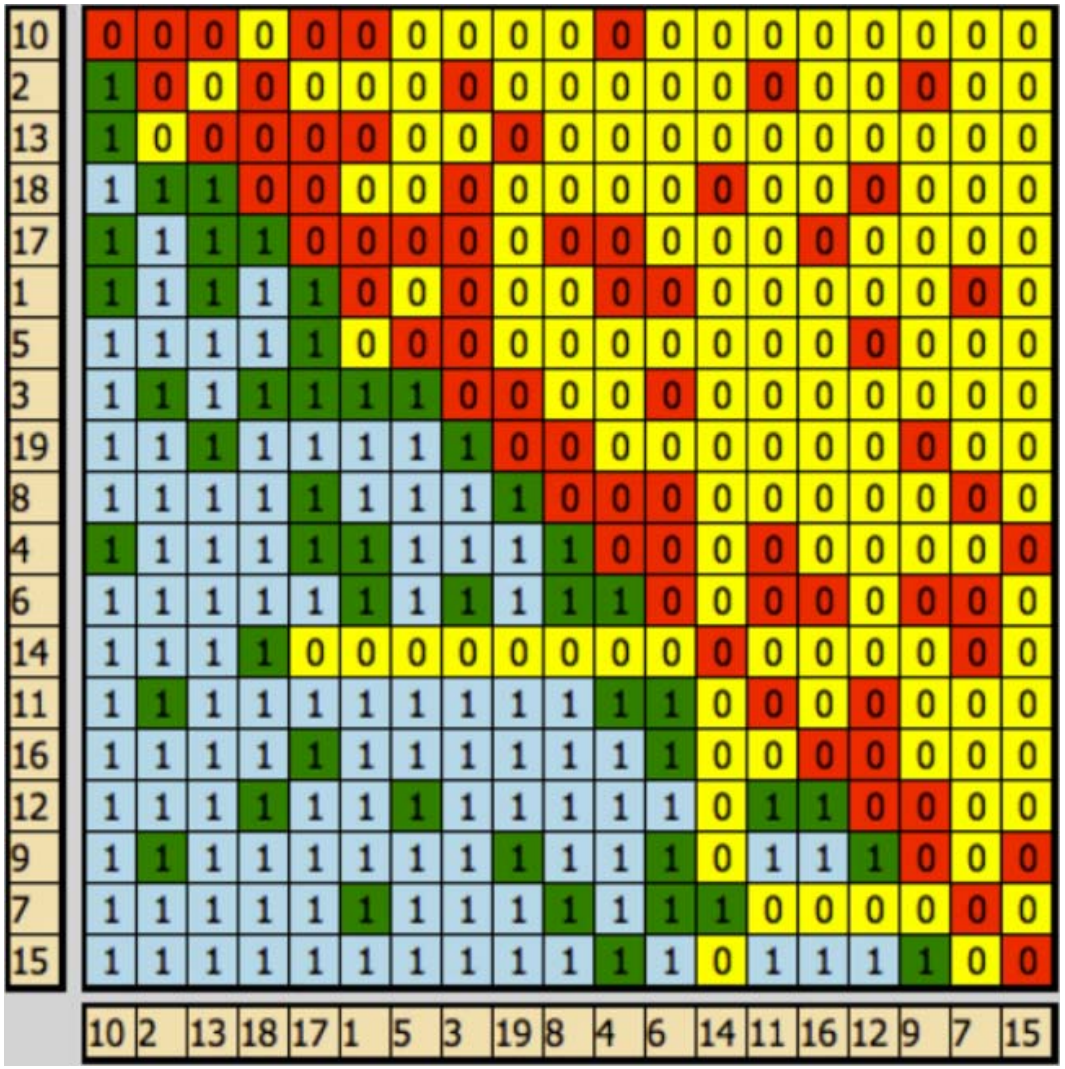
Final System Structure

Final System Structure



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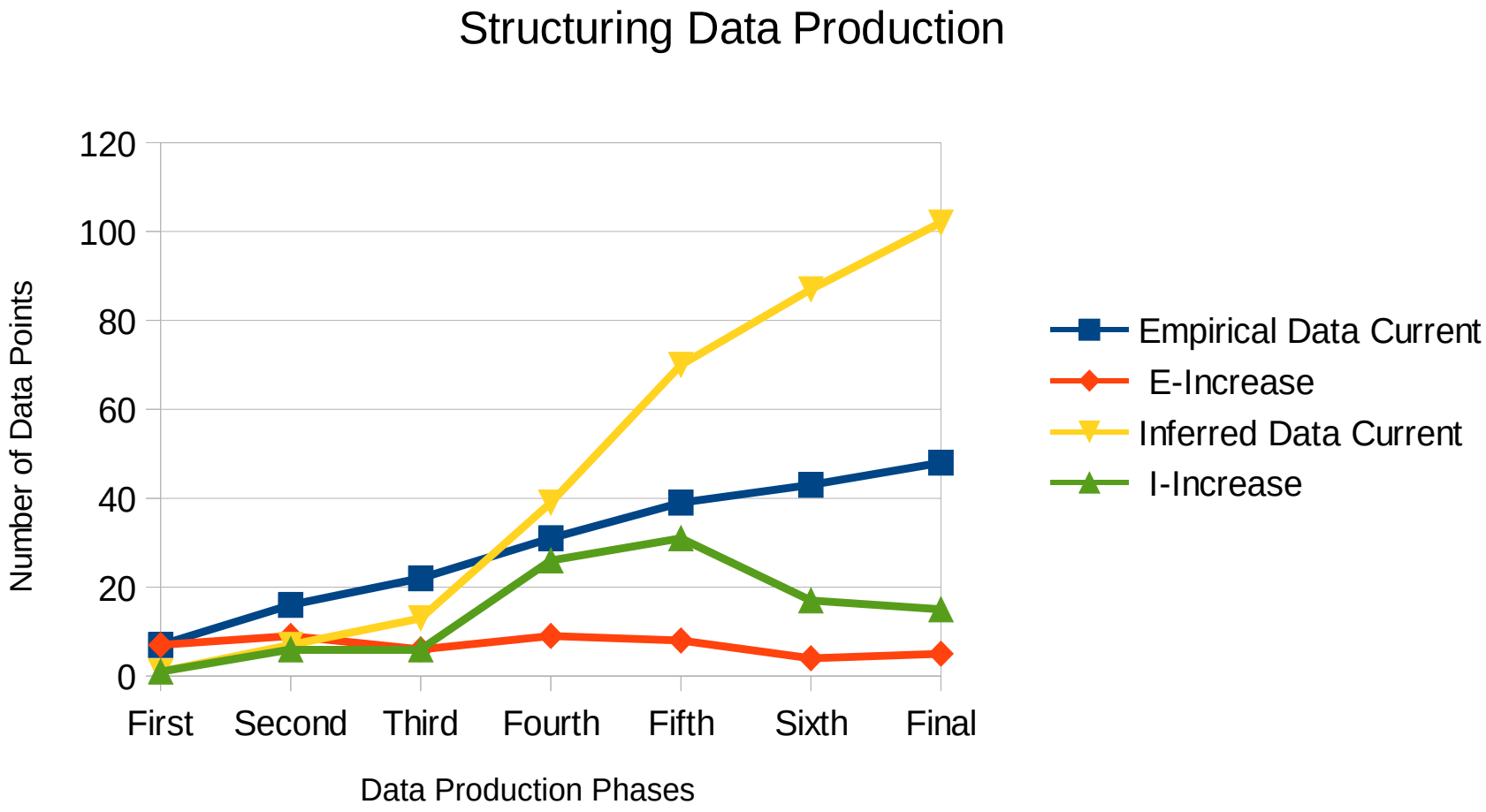
Empirical Data vs. Inferred Data

Data Production Phases	Number of Data Points			
	Empirical Data		**Inferred Data**	
	Current	E-Increase	Current	I-Increase
First	**7**	7	**1**	1
Second	**16**	9	**7**	6
Third	**22**	6	**13**	6
Fourth	**31**	9	**39**	26
Fifth	**39**	8	**70**	31
Sixth	**43**	4	**87**	17
Final	**48**	5	**102**	15

‘Structuring Data’ Production



Summary

- **Three components of structural modeling**
  - Basic Structural Models (BSM)
  - Interpretive Structural Models (ISM)
  - Structural Integration Modeling (SIM)
- **System organizing relationship is key to identify unknown system structure**
- **Structured mix of logic and empirical data**
- **Goal is to minimize data development cost**
- **Need to identify common strategies**
- **Area rich with opportunity**

Additional Information

Additional information is available

- http://systemsconcept.org/
- https://github.com/jjs0sbw

To join in the discussion and activity

Contact jjs0sbw@gmail.com

This presentation hits the highlights

More detail in the Thursday tutorial

Sign up for the email newsletter

Questions?

Types of Questions

A Good Question

I understand the question, **and** I have an answer.

An Excellent Question

I understand the question; I have an answer -

and charts!

An Interesting Question

I have no idea what you are talking about…

Backup Slides

Types of Set Definition

Set Definition by Extension

All set members are enumerated

Set Definition by Intention

A set is described by listing the defining properties of the members