Foundational Aspects of System Complexity Reduction

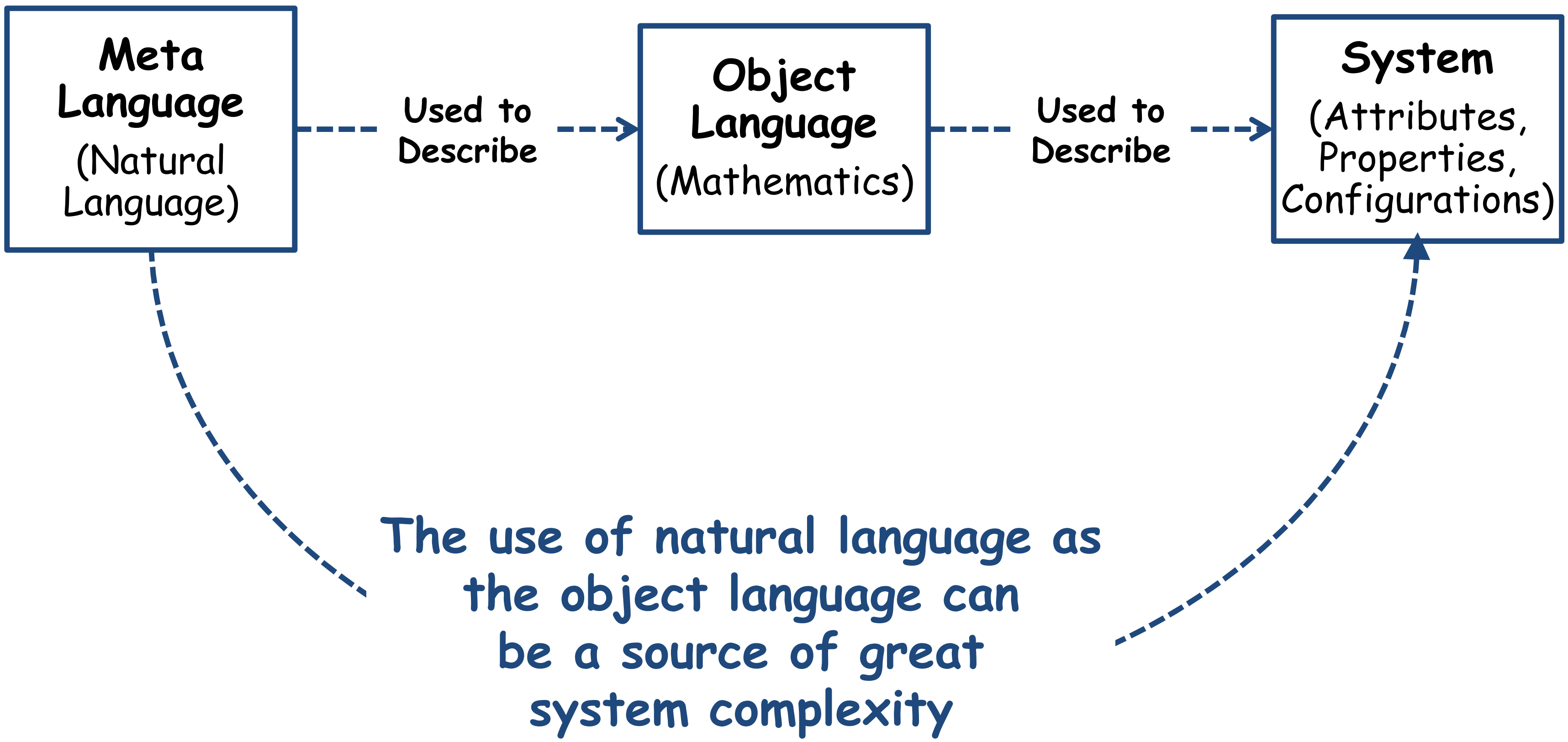
Joseph J Simpson
Mary J Simpson

Fundamental Approach

To Reduce Complexity

- **Reduce uncertainty**
- **Focus on a single system aspect, or organizing relationship**
- **Use two types of languages**
  - Natural language (informal)
  - Mathematics (formal)
- **Employ two structured interfaces**
  - Natural language to mathematics
  - Mathematics to system description

Language Types



Four Example Applications

- **Ex. 1: Combs Filter**
  - Union Rule Configuration (rule reduction)
- **Ex. 2: Interpretive Structural Modeling (ISM)**
  - Augmented Model-Exchange Isomorphism (pattern identification)
- **Ex. 3: Automated N-Squared Charts**
  - Evolutionary Computation (cognitive complexity reduction)
- **Ex. 4: Abstract Relation Types (ART)**
  - Information Theory (computational complexity reduction)
  - Structured Format and Approach (cognitive complexity reduction)

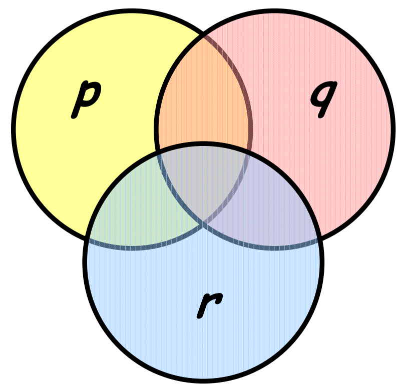
Ex. 1: Combs Filter - URC

- **Typical logic rules written with logical '*and*' conjunction - Intersection Rule**
  - Binds **two or more** antecedents to the rule consequent
- **Combs Filter written with logical '*or*' conjunction - Union Rule**
  - Binds **one** antecedent to a consequent
  - Provides access for alternative rule development and configuration
- **Boolean Reasoning**
  - Provides opportunity for methods other than Boolean Minimization

Intersection vs Union

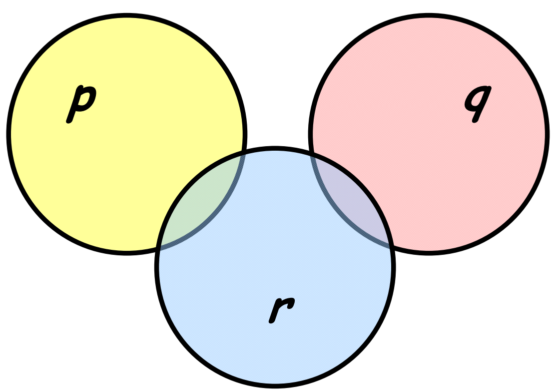
Intersection Rule Configuration

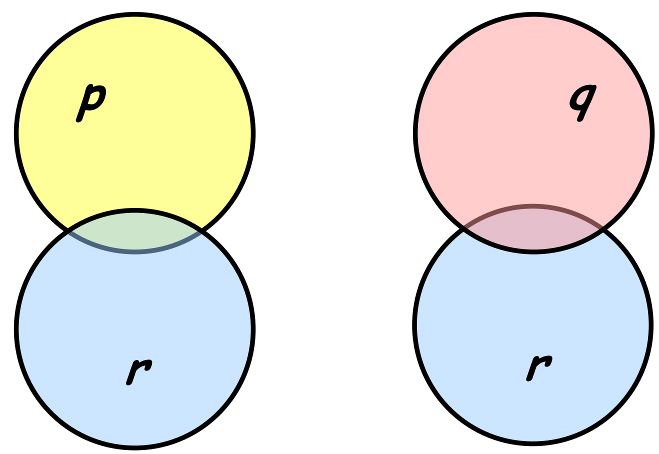
(*p* and *q*) then *r*



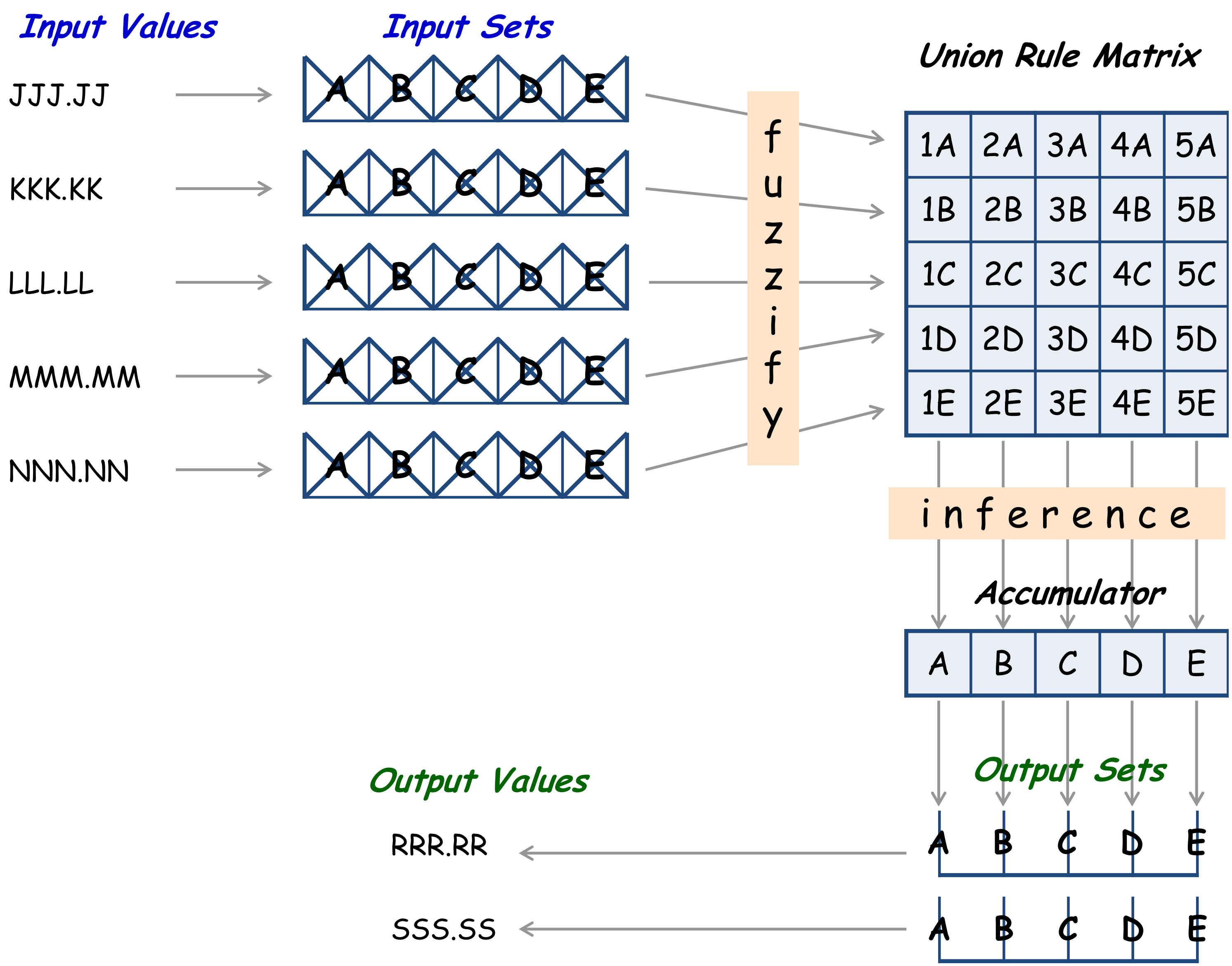
Union Rule Configuration

(*p* then *r*) **or** (*q* then *r*)





Union Rule Configuration



Adapted from Figure A.16, Combs, 1999.

Ex. 2: Interpretive Structural Modeling (ISM)

Abstract Relation Type (ART)

Prose Description (text, words)

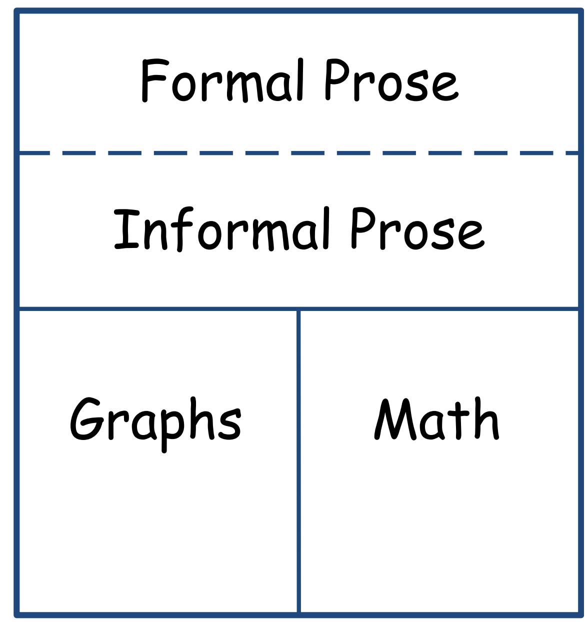
- Formal pattern
- Informal prose

Graphic Representation (directed graphs)

- Must have formal graphs
- Can also have informal graphs

Mathematics & Computer Representation

- Math equations
- Computer codes
- One or both



Augmented Model-Exchange Isomorphism

Abstract

Relation

Type

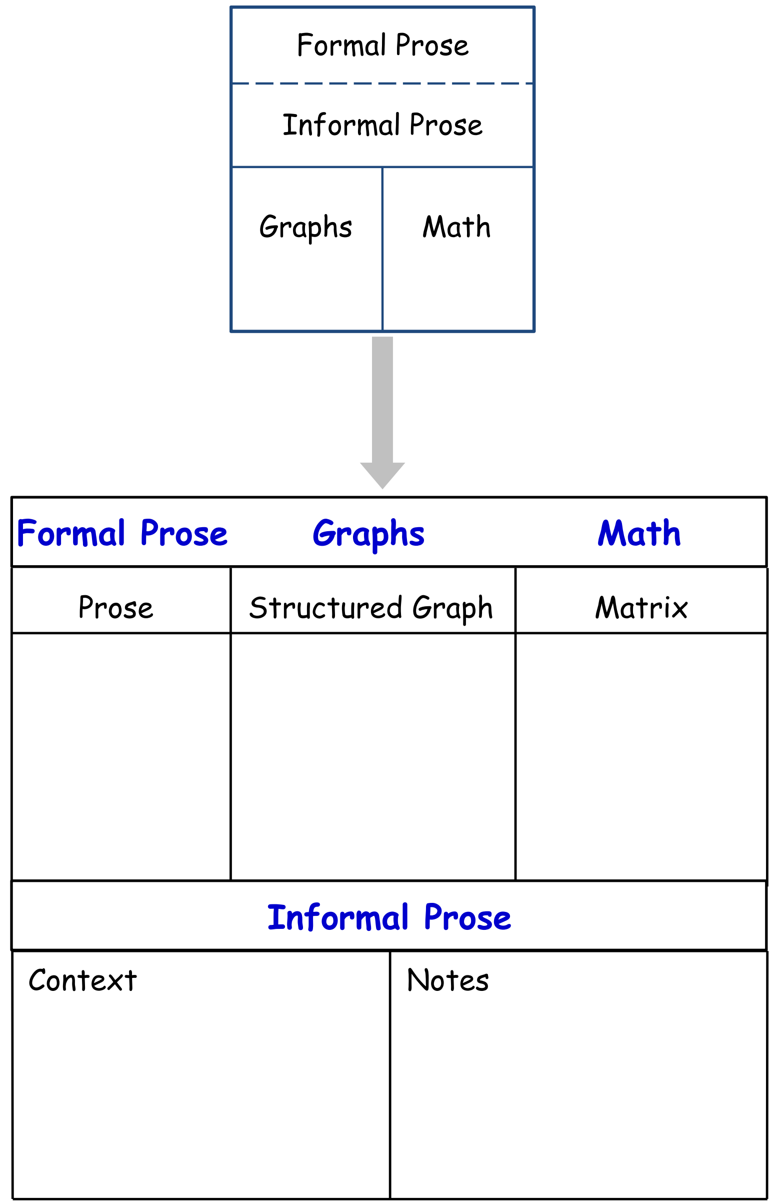
Reflected in

Augmented

Model

Exchange

Isomorphism



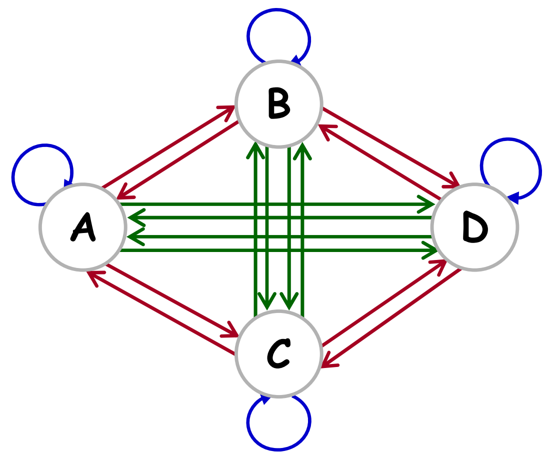
Typical ISM Relation

Prose	Structured Graph	Matrix

Relation 'Connected-to'

- Reflexive
- Symmetric
- Transitive

RST-[1,1,1] v1.1



	A	B	C	D
A	1	1	1	1
B	1	1	1	1
C	1	1	1	1
D	1	1	1	1

Context

1. Directional connections
2. Double directions
3. Self-connection required

Notes

1. Shows transitive links

Ex. 3: Automated N-Squared Chart

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

No Obvious Pattern; Unordered

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

Ordered; Obvious Patterns

Adapted from Figure 8.13, Hitchins, 2003.

Evolutionary Computation

Ubiquitous, inexpensive computing power makes this approach more attractive now, than when computing power was very expensive

- Performs large scale search for best configuration
- Selects a small number of candidate configurations for expert review
- Uses one system configuration that is known at the beginning of the process

Remove From Computation

E	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1	H	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	C	1	0	0	0	0	0	0	0	0	0	0	0
0	0	1	G	1	0	0	0	0	0	0	0	0	0	0
0	0	1	1	A	1	0	0	0	0	0	0	0	0	0
0	0	1	0	1	I	1	0	0	0	0	0	1	0	0
0	0	0	0	0	1	J	1	1	1	1	1	0	0	0
0	0	0	0	0	0	1	K	1	1	1	1	0	0	0
0	0	0	0	0	0	1	1	L	1	1	1	0	0	0
0	0	0	0	0	0	1	1	1	O	1	1	0	0	0
0	0	0	0	0	0	1	1	1	1	N	1	0	0	0
0	0	0	0	0	0	1	1	1	1	1	O	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0	D	1	1
0	0	0	0	0	0	0	0	0	0	0	0	1	B	1
0	0	0	0	0	0	0	0	0	0	0	0	1	1	F

Compress

E	1	1	0	0	0	0	0	0	0
1	H	1	0	0	0	0	0	0	0
1	1	C	1	0	0	0	0	0	0
0	0	1	G	1	0	0	0	0	0
0	0	1	1	A	1	0	0	0	0
0	0	1	0	1	I	1	1	0	0
0	0	0	0	0	1	J	0	0	0
0	0	0	0	0	1	0	D	1	1
0	0	0	0	0	0	0	1	B	1
0	0	0	0	0	0	0	1	1	F

Expand

Compress Again

E	1	1	0	0	0	0	0	0	0
1	H	1	0	0	0	0	0	0	0
1	1	C	1	0	0	0	0	0	0
0	0	1	G	1	0	0	0	0	0
0	0	1	1	A	1	0	0	0	0
0	0	1	0	1	I	1	1	0	0
0	0	0	0	0	1	J	0	0	0
0	0	0	0	0	1	0	D	1	1
0	0	0	0	0	0	0	1	B	1
0	0	0	0	0	0	0	1	1	F

Compress C and D

C	1	0	0	0	0
1	G	1	0	0	0
1	1	A	1	0	0
1	0	1	I	1	1
0	0	0	1	J	0
0	0	0	1	0	D

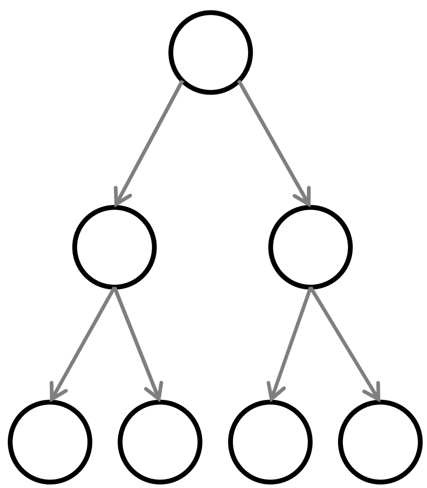
Expand C and D

Ex. 4: Use of Structured ART Format

Organizing Properties of Symmetry

Asymmetric

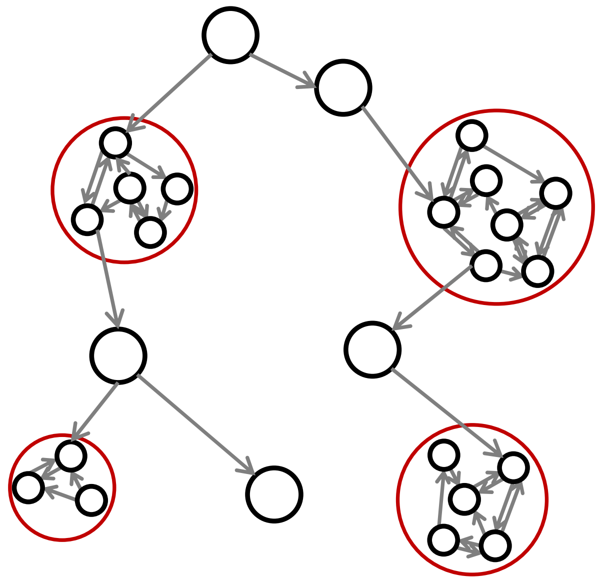
Hierarchy



- Use logic rules to discover structure in an efficient manner
- Analyze structure

Nonsymmetric

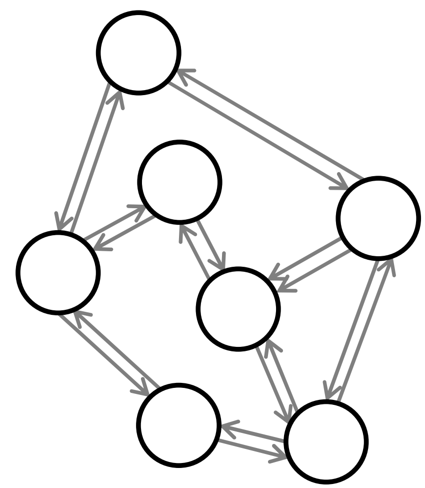
Combined Hierarchy & Network



- Apply lattice and set partitioning rules to identify components
- Apply other techniques as needed

Symmetric

Network



- Analyze for highest value configuration
- Filter out controlling structure
- Analyze structure

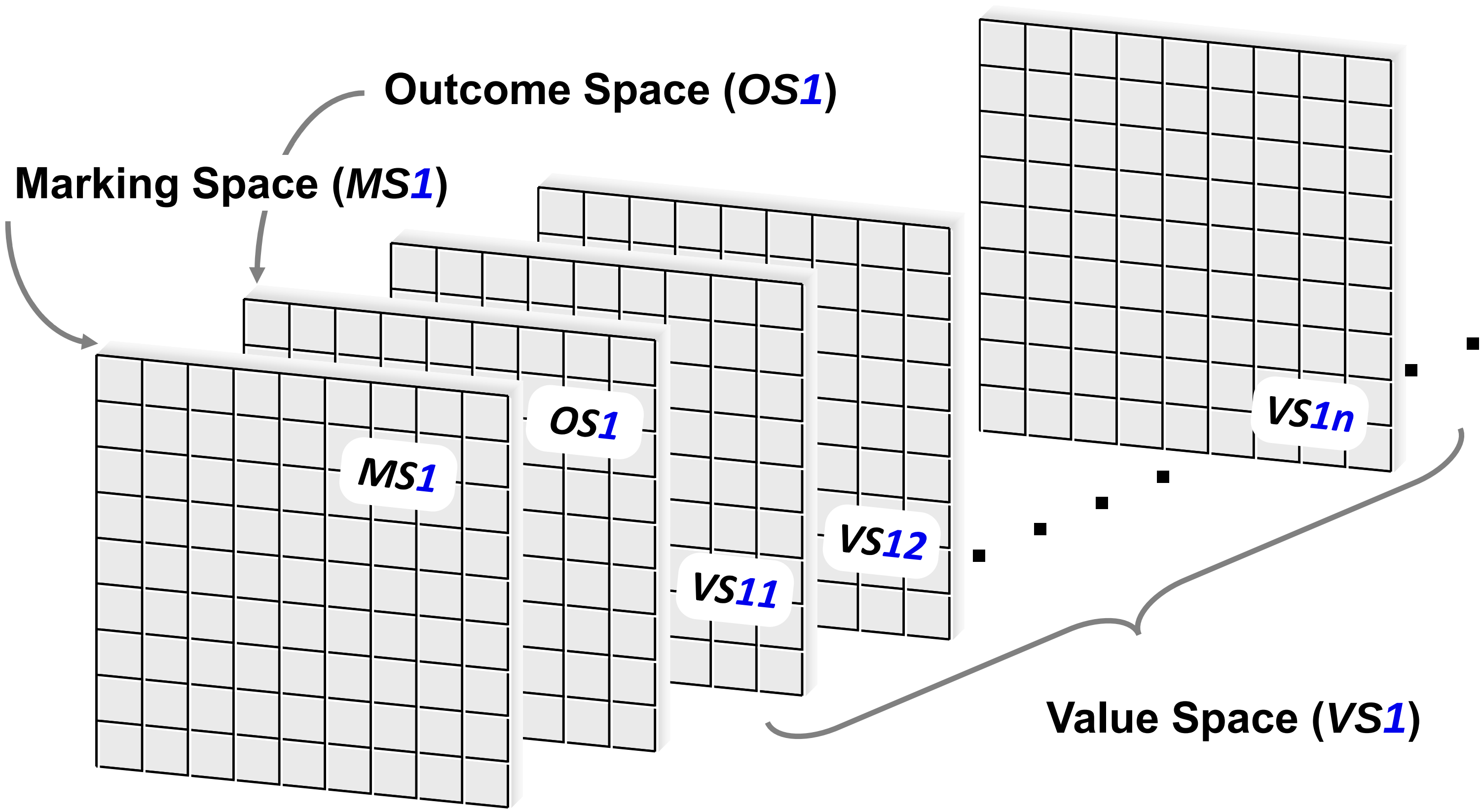
Information Theory

Information theory contributions to complexity reduction

- A message contains no information, if you already know the contents of the message
- A message contains information, if you do not know the contents of the message
- Computational effort should not be applied to messages that contain known information

Both cognitive and computational complexity are reduced

Structured ART Approach



Abstract Relation Type (*ART*) ≡ Ƒ [*MS, OS*]

Outcome Space (*OS*) ≡ Ƒ [$VS_1, VS_2, \ldots VS_n, VS_{n+1}, \ldots$]

Summary

- **Combs Filter**
  - Great reduction in number of rules
- **Interpretive Structural Modeling (ISM)**
  - Cognitive and computational complexity reduction achieved using the proper approaches
- **Automated N-Squared Charts**
  - Cognitive complexity reduction
- **Abstract Relation Types (ART)**
  - Computational complexity reduction
  - Cognitive complexity reduction

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

Exponential Rule Explosion
(The Curse of Dimensionality)

System Concepts[SM]

Number of rules (**N**) that have to be considered is equal to
the number of values per antecedent (**a**)
raised to the power of the number of antecedents (**b**)

$$\mathbf{N = a^b}$$

N = Number of values per antecedent	a = Number of antecedents	b = Number of rules
5	1	5
5	2	25
5	3	125
5	4	625
5	5	3,125
5	6	15,625
5	7	78,125
5	8	390,625

Exponential Rule Explosion - Example

Five Values per Antecedent - Two Antecedents		
Antecedent (**AGE**)	Values: *Youthful, Young, Middle-Aged, Mature* , or *Old*	
Antecedent (**HEALTH**)	Values: *Excellent, Good, Average, Below Average* , or *Poor*	
Rule 1 –	If AGE is Youthful and HEALTH is Excellent	then premium is very low
Rule 2 –	If AGE is Young and HEALTH is Excellent	then premium is low
Rule 3 –	If AGE is Middle-Aged and HEALTH is Excellent	then premium is mod-low
Rule 4 –	If AGE is Mature and HEALTH is Excellent	then premium is mod-low
Rule 5 –	If AGE is Old and HEALTH is Excellent	then premium is moderate
Rule 6 –	If AGE is Youthful and HEALTH is Good	then premium is low
Rule 7 –	If AGE is Young and HEALTH is Good	then premium is mod-low
Rule 8 –	If AGE is Middle-Aged and HEALTH is Good	then premium is mod-low
Rule 9 –	If AGE is Mature and HEALTH is Good	then premium is moderate
Rule 10 –	If AGE is Old and HEALTH is Good	then premium is mod-high
Rule 11 –	If AGE is Young and HEALTH is Average	then premium is mod-low
Rule 12 –	If AGE is Youthful and HEALTH is Average	then premium is mod-low
Rule 13 –	If AGE is Middle-Aged and HEALTH is Average	then premium is moderate
Rule 14 –	If AGE is Mature and HEALTH is Average	then premium is mod-high
Rule 15 –	If AGE is Old and HEALTH is Average	then premium is mod-high
Rule 16 –	If AGE is Youthful and HEALTH is Below-Average	then premium is mod-low
Rule 17 –	If AGE is Young and HEALTH is Below-Average	then premium is Moderate
Rule 18 –	If AGE is Middle-Aged and HEALTH is Below-Average	then premium is mod-high
Rule 19 –	If AGE is Mature and HEALTH is Below-Average	then premium is mod-high
Rule 20 –	If AGE is Old and HEALTH is Below-Average	then premium is high
Rule 21 –	If AGE is Youthful and HEALTH is Poor	then premium is moderate
Rule 22 –	If AGE is Young and HEALTH is Poor	then premium is mod-high
Rule 23 –	If AGE is Middle-Aged and HEALTH is Poor	then premium is mod-high
Rule 24 –	If AGE is Mature and HEALTH is Poor	then premium is high
Rule 25 –	If AGE is Old and HEALTH is Poor	then premium is very high

Relational Algebra for UR

Formal logic transformation steps for IR to UR

• **(*p* and *q*) then *r***	**the initial Intersection Rule**
• **not (*p* and *q*) or *r***	by material implication
• **(not *p* or not *q*) or *r***	by DeMorgan's law
• **not *p* or (not *q* or *r*)**	by association
• **(not *q* or *r*) or not *p***	by commutation
• **(*q* then *r*) or not *p***	by material implication
• **((*q* then *r*) or not *p*) or *r***	by addition
• **(*q* then *r*) or (not *p* or *r*)**	by association
• **(*q* then *r*) or (*p* then *r*)**	by material implication
• **(*p* then *r*) or (*q* then *r*)**	by commutation
(*p* then *r*) or (*q* then *r*)	**the Union Rule**

Intersection & Union Rule 'Truth Tables'

[(*p* and *q*) then *r*] is equivalent to [(*p* then *r*) or (*q* then *r*)]

p	*q*	*r*	(*p* and *q*)	(*p* and *q*) then *r*	(*p* then *r*)	(*q* then *r*)	(*p* then *r*) or (*q* then *r*)
T	T	T	T	**T**	T	T	**T**
T	T	F	T	**F**	F	F	**F**
T	F	T	F	**T**	T	T	**T**
T	F	F	F	**T**	F	T	**T**
F	T	T	F	**T**	T	T	**T**
F	T	F	F	**T**	T	F	**T**
F	F	T	F	**T**	T	T	**T**
F	F	F	F	**T**	T	T	**T**

Adapted from Figure A.2, Combs, 1999.

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