Foundational Aspects of System Complexity Reduction

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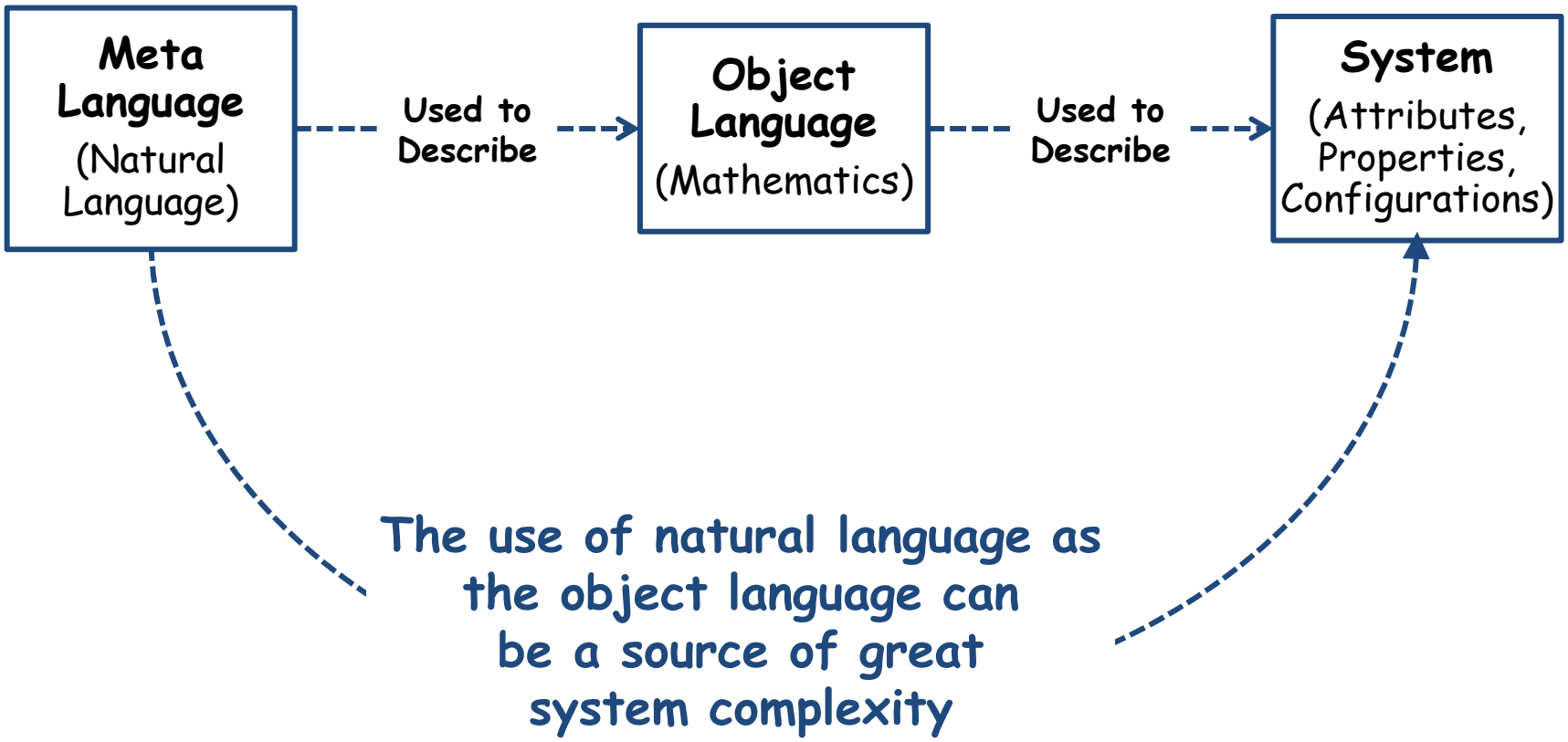
Fundamental Approach

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)

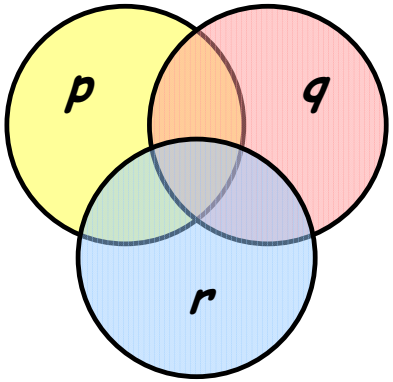
Ex. 1: Combs Filter - URC

- **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

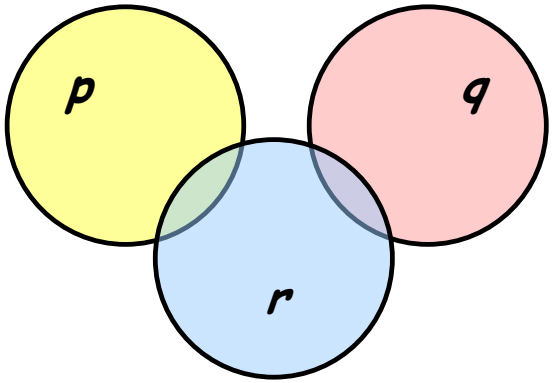
Intersection Rule Configuration

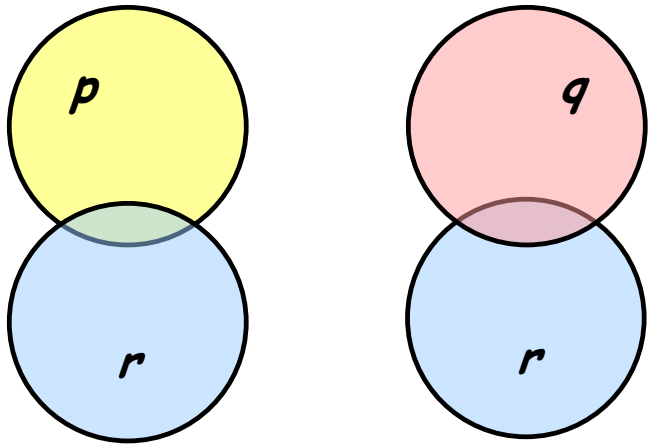
(*p* and *q*) then *r*



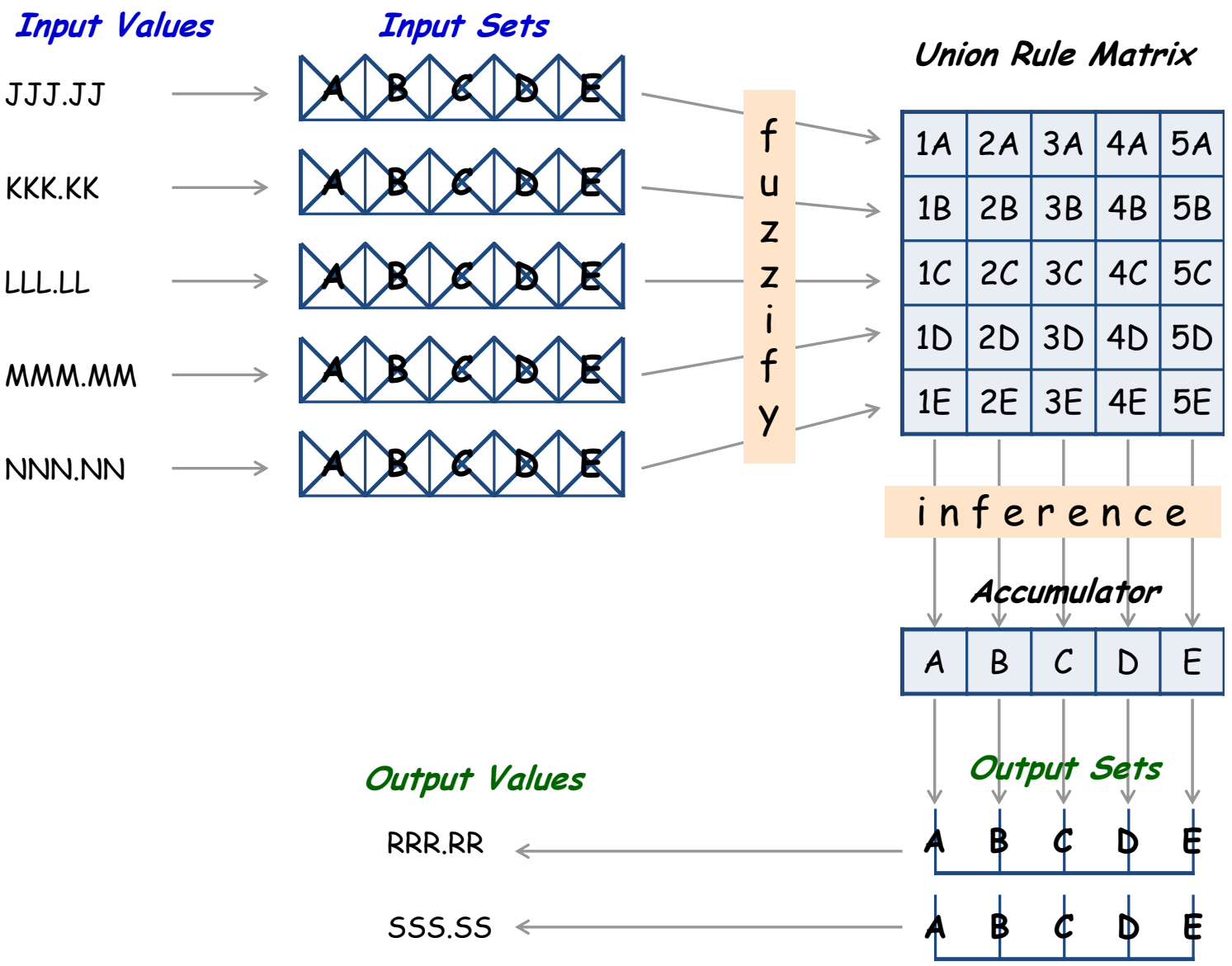
Union Rule Configuration

(*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)

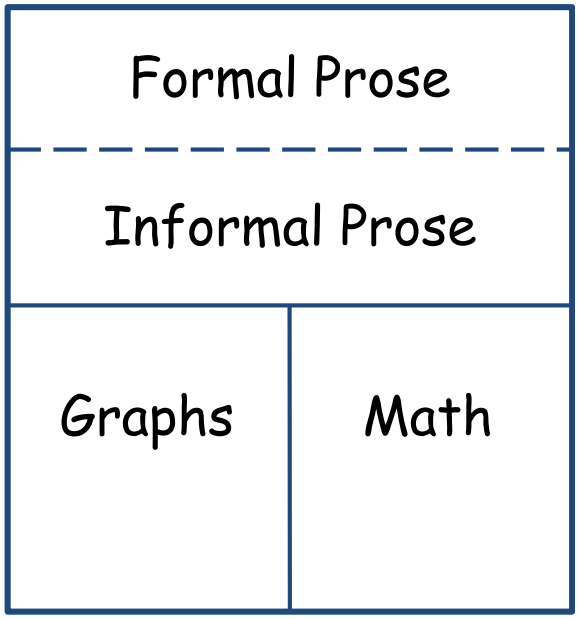
- Formal pattern
- Informal prose

Graphic Representation
(directed graphs)

- Must have formal graphs
- Can also have informal graphs

Mathematics & Computer Representation

- Math equations
- Computer codes
- One or both

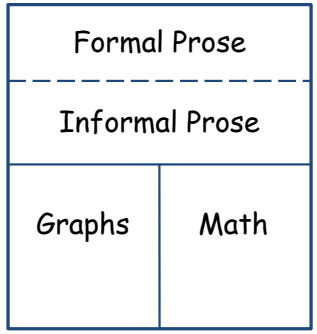


Augmented Model-Exchange Isomorphism

Abstract Relation Type

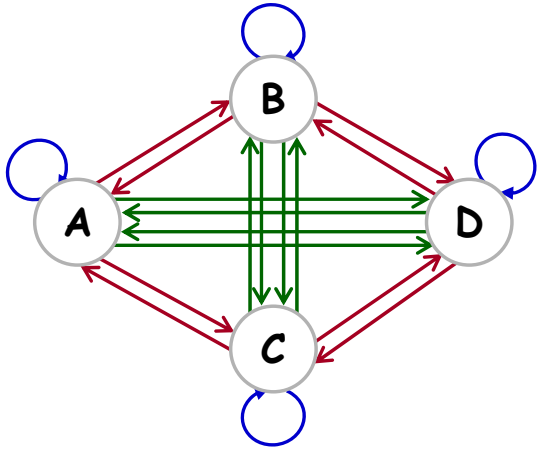
Reflected in

Augmented Model Exchange Isomorphism



Formal Prose	Graphs	Math
Prose	Structured Graph	Matrix
Informal Prose		
Context	Notes	

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

Expand

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 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

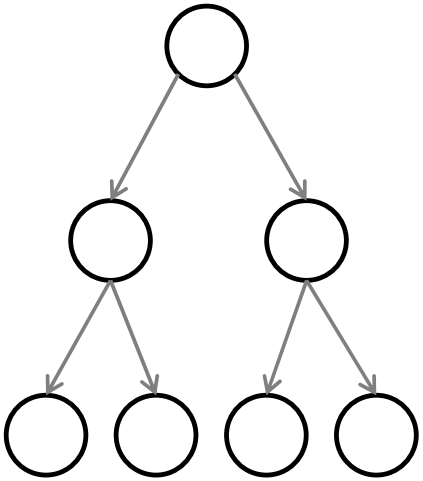
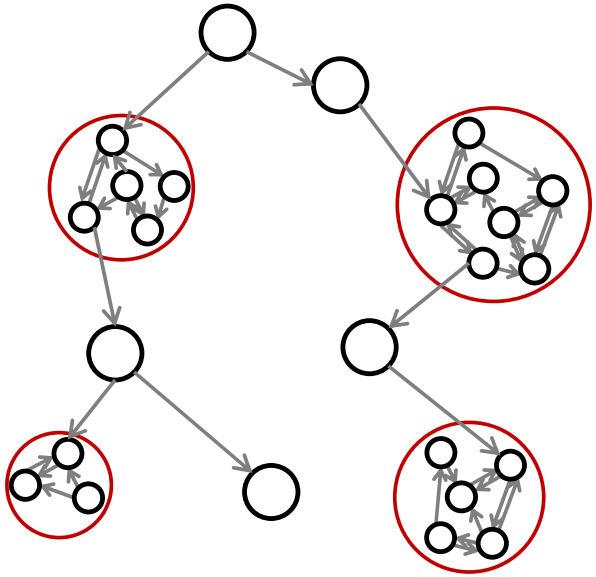
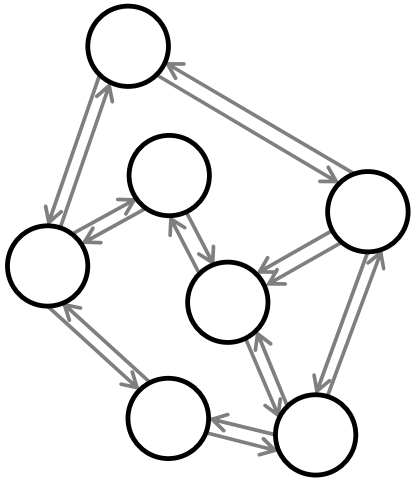
Compress C and D

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	Nonsymmetric	Symmetric
Hierarchy	Combined Hierarchy & Network	Network
		
• Use logic rules to discover structure in an efficient manner • Analyze structure	• Apply lattice and set partitioning rules to identify components • Apply other techniques as needed	• Analyze for highest value configuration • Filter out controlling structure • Analyze structure

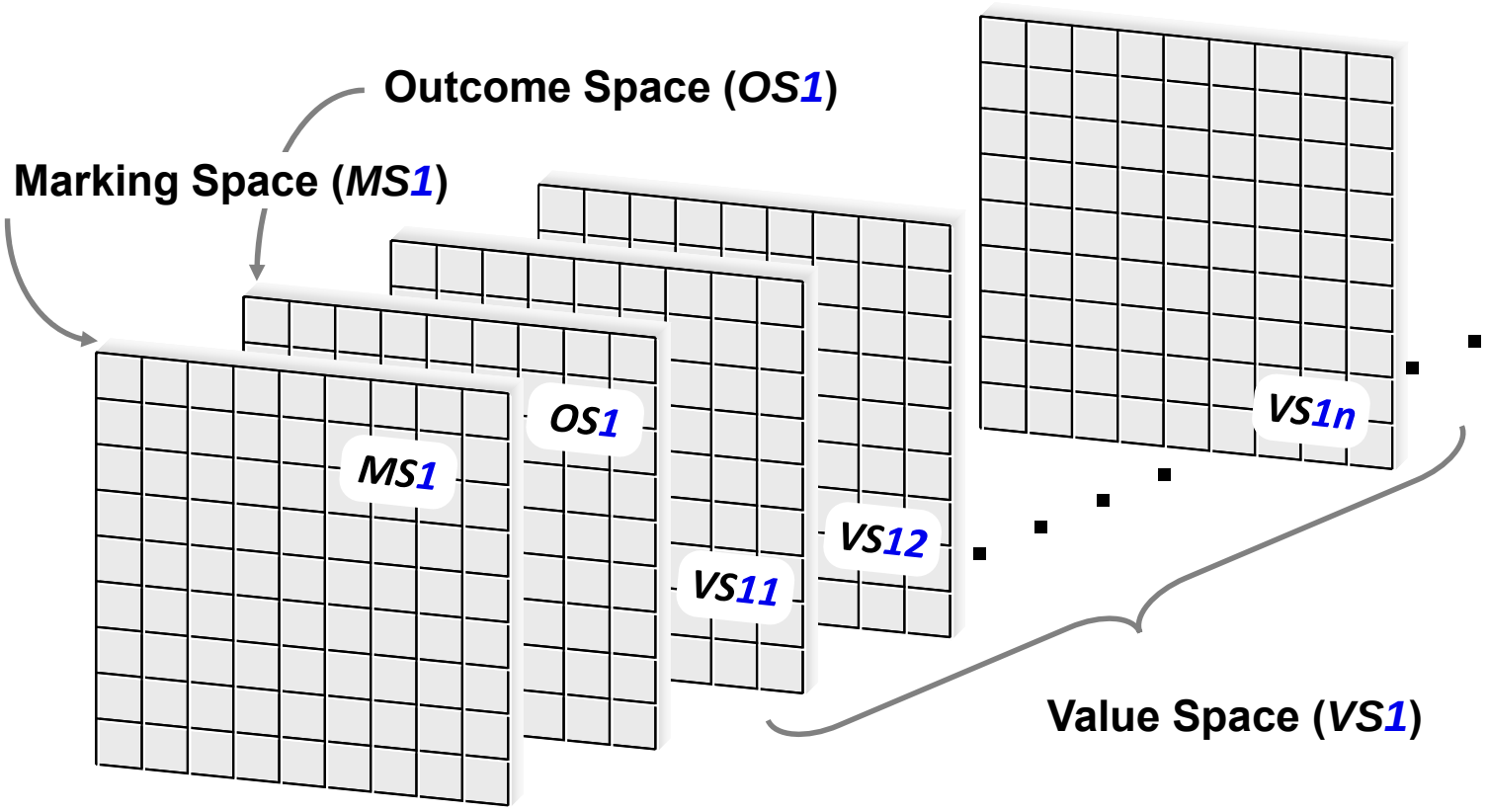
Information Theory

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*) ≡ ∫ [*MS, OS*]

Outcome Space (*OS*) ≡ ∫ [VS_1, VS_2, …VS_n, VS_{n+1}, …]

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

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Questions?