System of Systems Complexity Identification and Control

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Systems Concepts

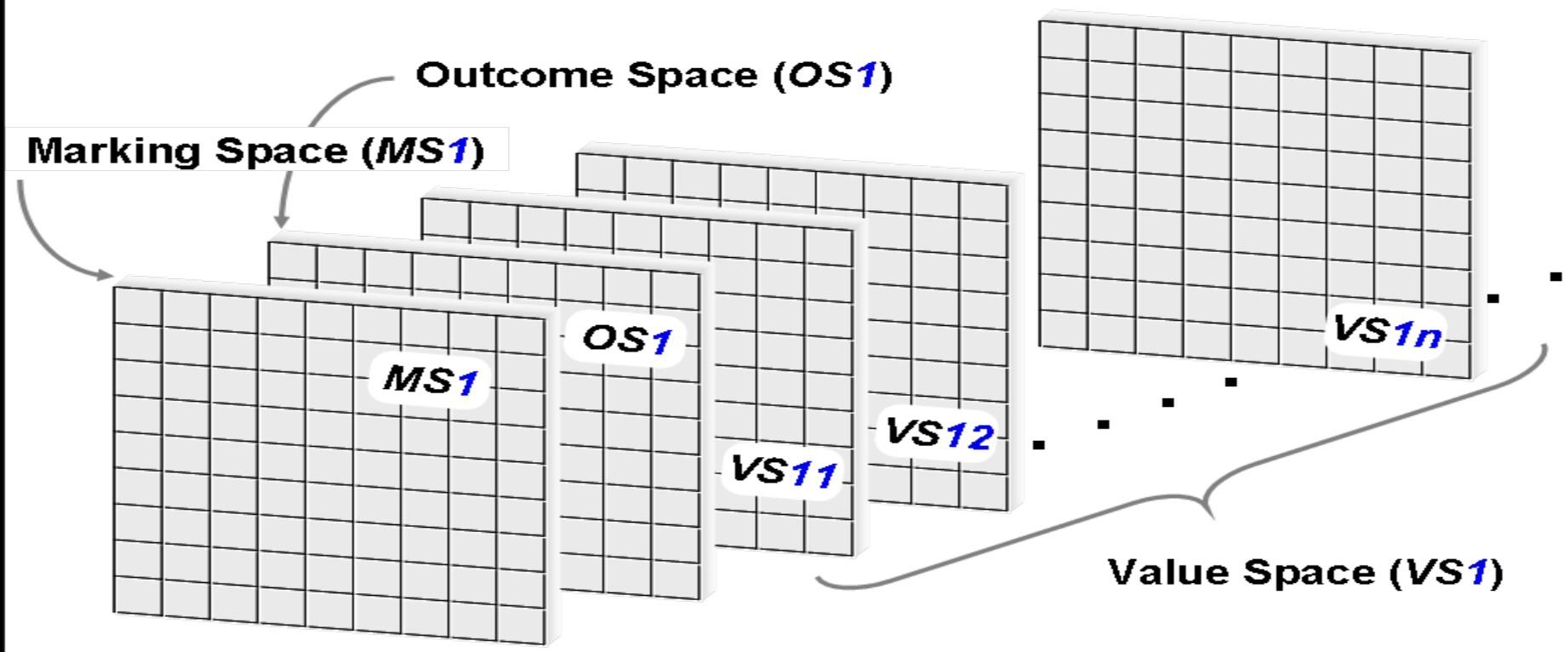
Overview

- Introduction
- Abstract Relation Types (ART)
- N Squared Charts
- Design Structure Matrices (DSM)
- Complexity Identification and Control
- DSM ART
- Evolutionary Algorithm ART Method
- Summary and Conclusion

Introduction

- Define Three Complexity Types
- Abstract Relation Type Components
- Classical Uses of N Squared and DSM
- Cognitive Complexity Identification
- ART Evolutionary Algorithm for Complexity Reduction
- Global Relation Combined With Local Value and/or Function

Abstract Relation Types



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

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

N Squared Charts

- Initially developed as a system analysis and interface communication tool for software design and development.
- Proved to be well suited for the grouping of alternative system configurations
- Mostly used to communicate system structure
- Based on analysis by human experts

Design Structure Matrix DSM

- First developed to address the reduction of computational complexity in sets of linear equations
- Was recognized as a powerful graphical tool to communicate large amounts of detailed information to groups of diverse individuals
- Is developing into a number of different, varying techniques each with unique syntax and semantics

Cognitive Complexity Identification

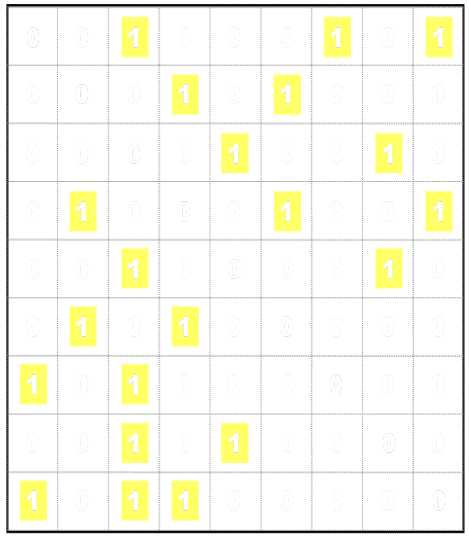
- John N. Warfield, Science of Generic Design and The Mathematics of Structure
- Clear development of complexity concepts and reduction approaches
- Contains three equivalent forms; prose, graphics and mathematics
- Applies to ideas and concept development

DSM ART

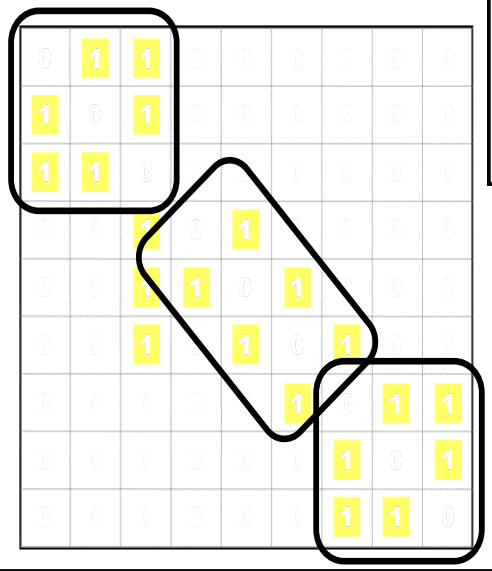
- System structure is separated from system value
- Marking space based of Warfield Mathematics of Structure – Augmented Boolean Mathematics
- Value space based of Hitchins Automated N Squared Charts
- Evolutionary algorithm ART method generates candidate solutions automatically, reducing the cost of human systems analysis and creating solutions not seen by the human analyst.

Evolutionary Algorithm ART Method

0	1	2	3	4	5	6	7	8
1	0	1	2	3	4	5	6	7
2	1	0	1	2	3	4	5	6
3	2	1	0	1	2	3	4	5
4	3	2	1	0	1	2	3	4
5	4	3	2	1	0	1	2	3
6	5	4	3	2	1	0	1	2
7	6	5	4	3	2	1	0	1
8	7	6	5	4	3	2	1	0

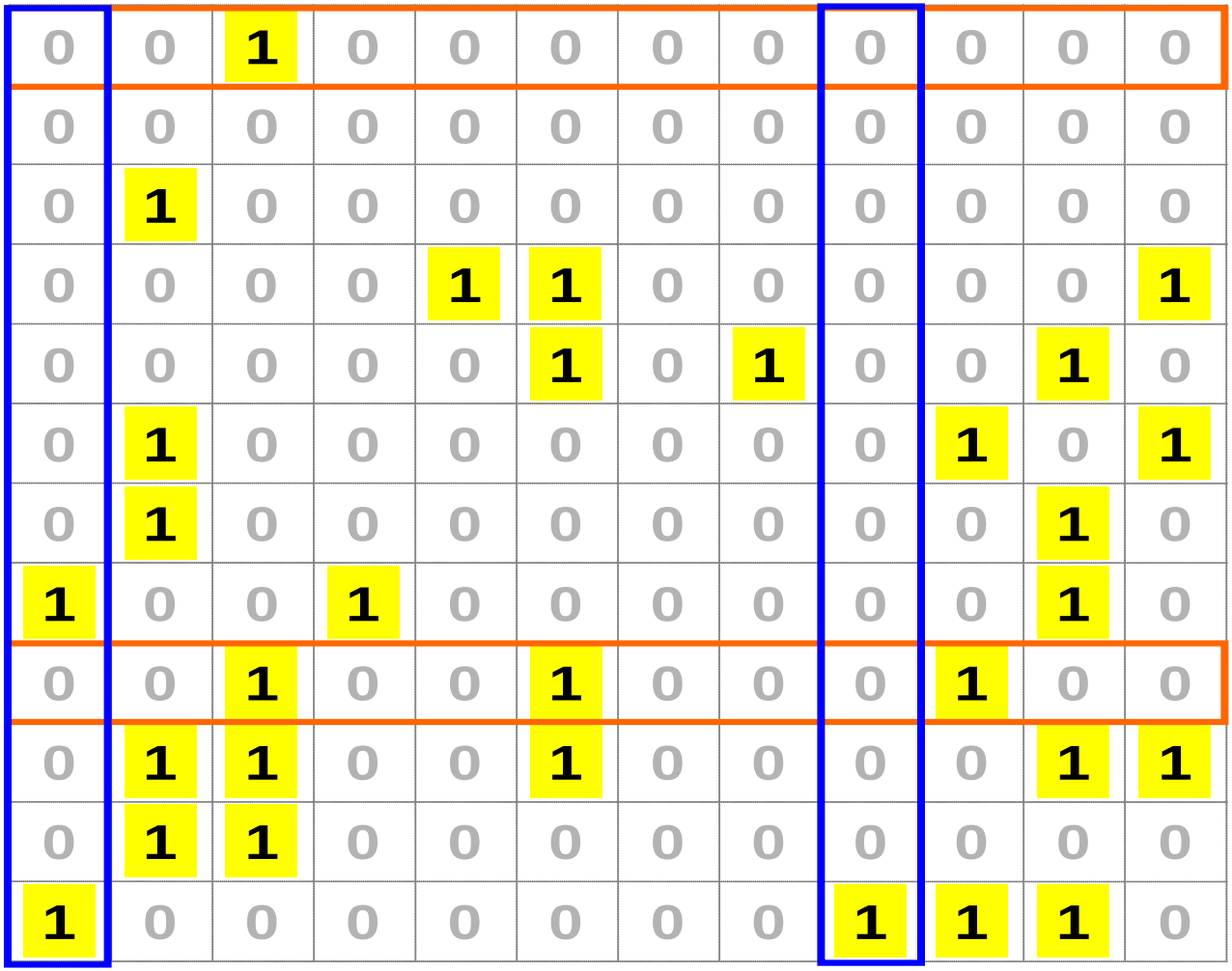


Unordered Marking Space; No Obvious Pattern



Ordered Marking Space; Obvious Patterns

Evolutionary Algorithm ART



Summary and Conclusions

- ART provide a framework for the communication and documentation of classical systems engineering techniques
- ART support the combination of classical techniques and emerging modern techniques in a manner that provide measurable cognitive complexity reduction.
- There is some indication that ART techniques can also reduce computational complexity.