Automated DSM Analysis

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Overview

- Three Major Points Of Discussion
  - The Intended Topic
  - A Little More Focused Research
  - A New Direction

The Intended Topic

- DSM Analysis
- Usefulness Of The DSM
- Original Problem Statement

The Intended Topic - DSM Analysis

- What is a DSM?
- A Design Structure Matrix (DSM) is a method of modeling a system design utilizing a N x N matrix, where N represents the components in the system.
- Essentially, a matrix representation of a dependency graph of the system being modeled.

The Intended Topic - Usefulness

- Goals
  - Optimize The Flow Of “Data” Through The System
  - Identify Coupled Components Within The System
- Optimization of these two objectives can provide a great deal of insight into how a system should be architected.
- Currently a very manual process relying on human expertise.

The Intended Topic - Original Problem Statement

- This report seeks to investigate the optimization of a Design Structure Matrix to a family of potential solutions. Through this process, an algorithmic method will need to be found to identify and understand the difference between obvious optimizations consistent across the family of solutions and which optimization points may lend themselves to a further trade analysis. As a part of the family of solutions, automatic identification of system modules in the various solutions will aid in the trade analysis. Methods from Artificial Intelligence will be employed as the basis for both the search for solutions and the identification of modules within the solutions.

The Intended Topic - Original Problem Statement

- Two General Goals
  - Determine a method for automatically optimizing a DSM and identifying potential trade analysis points. This would provide a “family” of solutions.
  - Automatically identify components within the system utilizing techniques from Artificial Intelligence.

A Little More Focused Research

- Selected the second problem statement as a focus for research for the semester.
- Background in Artificial Intelligence lead to this decision.
- The name of this game is Heuristics.

A Little More Focused Research - A Quick AI Background

- Artificial Intelligence
  - “The branch of computer science that is concerned with the automation of intelligent behavior” - Luger & Stubblefield (1993)
  - “The art of creating machines that perform functions that require intelligence when performed by people” - Kurzweil (1990)

A Little More Focused Research - A Quick AI Background

- AI is generally all about searches. Searches through a problem space & searches through a knowledge base.
- Identifying the components within a DSM is a search through a problem space.

A Little More Focused Research - A Quick AI Background

- Basic Search Technique

```
function SEARCH(g, s) returns a state
    Inputs: g, a goal
            s, a state space
    IF the current state, s, satisfies the goal g, then
    return the state

    ELSE determine the next state and
    return SEARCH(g, s[next])
```

A Little More Focused Research - A Quick AI Background

- The goal in many cases is a simple equality, i.e. does the state equal my goal, or is the state less than my goal, etc…
  - A simple string search may look for a string to be found within a text document.
- In typical AI problems, there is not a simple goal. This goal is often referred to as the objective function.
- The objective function is generally a heuristic search rather than an algorithmic search. Looking for a "good" answer rather than an exact answer.

A Little More Focused Research - A Quick AI Background

- Heuristic Example - Solving A 9 Tile Puzzle
  - A normal algorithm would look for an exact answer to this problem.
  - Problem lies in that to get to an answer the puzzle may become even further from a solution before it is solved.
  - A potential heuristic would look to see if overall the state space is approaching the correct ordering.

A Little More Focused Research - DSM Analysis

- Several techniques for searching came to mind to solve the problem of identifying components within the DSM but the design of the Objective Function seemed to be the challenge.
- Further research confirmed this as an issue.
  - Search techniques such as Simulated Annealing, Genetic Algorithms, and other searches in the “Hill Climbing” class have been researched.
  - This class of search all uses a heuristic objective function and varies in the way that the search moves between states.
  - Challenge often lies within defining the objective function.

A Little More Focused Research - DSM Analysis

- A Genetic Algorithm Case Study:
  - Work by Yu et al showed that a Genetic Algorithm (GA) could be more accurate at identifying clusters.
    - Saw the equivalent to human analysis after 10 simulated “generations” and saw a leveling off of results at 20 “generations” and finally stopped with a maximized system at 40 “generations”.
  - The algorithm, however, was not able to take into account several parameters that made a human analysis far more appropriate and useful.
  - There is certainly a good start with the research that has been done, but there is definitely room for improvement.

A New Direction

- While researching the DSM and optimization methods a number of methods were found that were adapting methods used in other industries for DSM optimization and analysis, such as the “real option” notion from economics.
- Stumbled upon a technique using a different brand of intelligence from Artificial Intelligence, Military Intelligence networks.

A New Direction - Terrorist Cells & Spy Networks

- A standard technique in determining a network of spies or terrorists involves grouping the individuals of interest in a matrix, marking interactions between the individuals in the matrix, and identifying interactions.
- Sound familiar?

A New Direction - Spy Network & DSM Compared

A Typical DSM

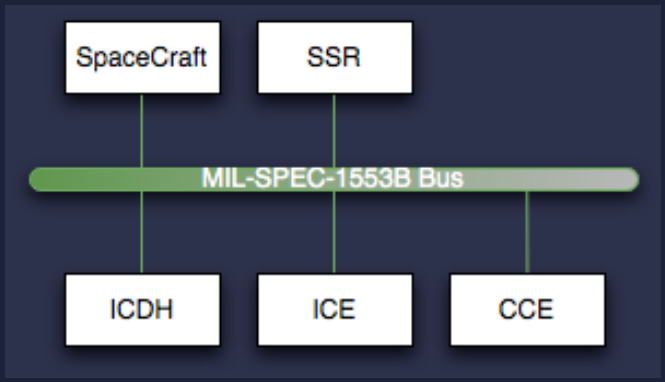
	1553 Bus	SpaceCraft	SSR	ICDH	ICE	CCE
1553 Bus		x	x	x	x	x
SpaceCraft	x		x			
SSR	x	x		x	x	x
ICDH	x		x		x	x
ICE	x		x	x		x
CCE	x		x	x	x	

A Potential Spy Network

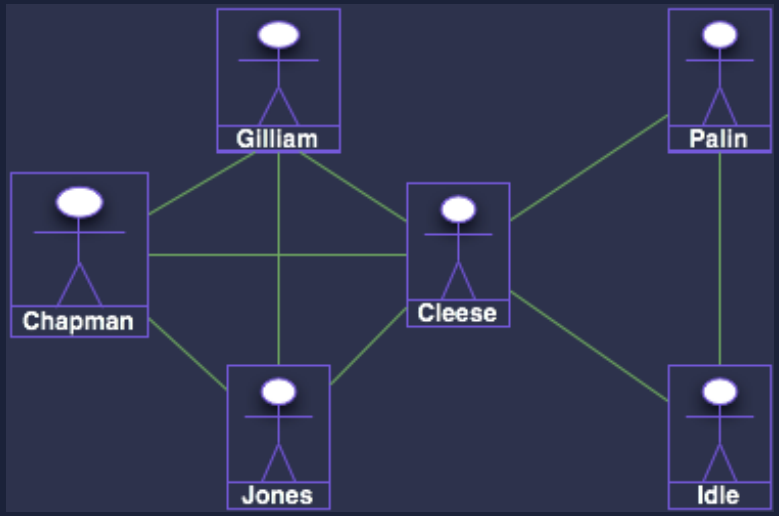
	Cleese	Palin	Idle	Chapman	Gilliam	Jones
Cleese		x	x	x	x	x
Palin	x		x			
Idle	x	x		x	x	x
Chapman	x		x		x	x
Gilliam	x		x	x		x
Jones	x		x	x	x	

A New Direction - Spy Network & DSM Compared

The System DSM Graphically



The Spy Network Graphically



The Bus Architecture DSM Pattern Is Identical To The Intelligence Network Checkerboard Pattern

A New Direction - Adapting Techniques

- The similarity between these data representations is striking and there is a large volume of research already done on intelligence techniques.
- Further research could yield not only techniques for identifying components but also additional methods for optimization.

A New Direction - Adapting Techniques

- Some similar work has been done for social network analysis, however the intelligence field brings in the specific concept of identifying clusters that are remarkably similar to system components.

Conclusions

- The study of techniques to analyze the DSM, both manually and automatically is still a relatively young field, as are many of the techniques of Artificial Intelligence.
- The similarities between techniques to study intelligence networks and potential DSM methodologies indicates a strong source for future study.

Question & Answer

- Questions?

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