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DSM BASED APPROACH FOR MANAGING REQUIREMENTS, RULES AND DESIGN PARAMETERS IN KNOWLEDGE BASED DESIGN PROCESS

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ABSTRACT
The development of Knowledge Based Systems for Engineering Design requires the capture, reuse and tracking of various kinds of design knowledge throughout the entire design process. Software engineering and Knowledge engineering principles have been used in the development of knowledge based systems (Bravo et al, 1999). These techniques are primarily applied in capturing and reusing the engineering knowledge. This paper proposes applying Design Structure Matrix (DSM) as a complementary methodology for not only capture and reuse, but also in analysing the impact of design changes and for managing the requirements and design rules. Lattix DSM tool has been used for tracking and managing various types of design knowledge during the entire lifecycle of the design process. This methodology works in conjunction with existing software engineering and knowledge engineering techniques and is applied to Aerospace design process.

1 KNOWLEDGE BASED DESIGN PROCESS

Aircraft Design process involves large amount of data and information (Wood and Bauer, 1998). Knowledge Based Design process captures the knowledge required at different stages of design. Typical design knowledge in a Knowledge Based Design Process includes requirements, specifications, product data, design rules, standards, geometry, configuration and engineering knowledge. And typical outputs of a KBE system are drawings, reports, costs, BOM, manufacturing data and CAD models. These data units are interdependent and are captured as part of the knowledge model (see Figure 1). As the complexity of the design problem increases the data and rules associated with the knowledge model become large and complex. In knowledge based design process core knowledge of a KBE system is captured as a product model (Sandberg, 2005), which is a combination of geometry, product configuration and rules. Various design inputs are fed into the product model which then generates the required outputs.

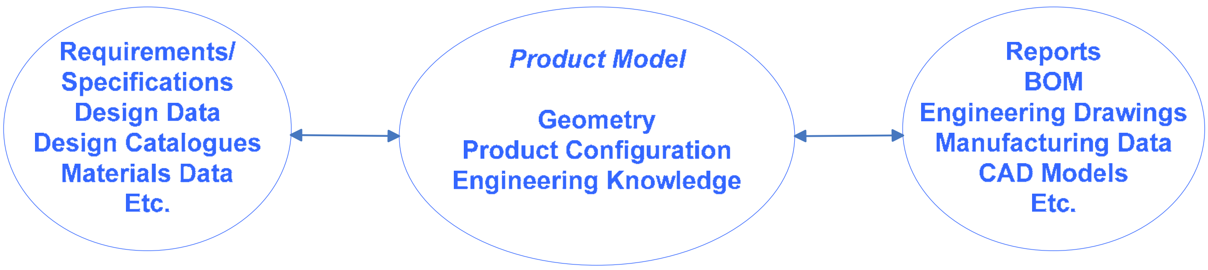

Figure 1. Typical data in a knowledge based design process

The product model is essentially a collection of design parts or objects along with their properties, interdependencies and behaviour. This is typically defined using Object Oriented methodology and represents the overall design process. To create an effective product model of the design domain, MOKA methodology (MML Working Group, 2000) can be used. MOKA (**M**ethodology and Tools **O**riented to **K**nowledge Based Engineering **A**pplications) uses informal and formal models to represent engineering knowledge. Engineering knowledge includes product as well as process knowledge. Informal model is structured, natural language representation of engineering knowledge. Formal model, an object oriented representation of engineering knowledge, is captured using MOKA modelling language (MML). MML is an extension of UML (Unified Modelling Language) and is specifically used in Knowledge Based Engineering.

Internal details of each design object are captured using simple variables, equations and rules. This creates a complex system with a formal network of design objects with their properties, rules and interfaces. As the system grows in complexity it is difficult to understand the flow of requirements, rules and parameters through the design process. It is also difficult to track design changes, perform impact analysis and redesign. Engineering design changes and their impact analysis is a complex process in itself. According to Kidd and Thompson (2000), Engineering design change management is a complex product life cycle activity and plays a crucial role in the success of a product. In a knowledge based design process this complexity multiplies due to the fact that a change can be at the design side or at the software side or both.

To reduce the system complexity and make it transparent, Design Structure Matrix techniques are applied at different stages of the design process. In a transparent system it is easier to view, understand and document the internal details. This helps in reducing the overall complexity of the system. DSMs with an Engineering Design perspective and Software Design perspective are created to capture and analyze the overall knowledge generated during the design process. These two DSMs are captured at different stages of the process. An Engineering DSM (see Figure 2) captures the overview of the design process knowledge in terms of engineering design activities. The basic essence of the product model is captured during this stage.

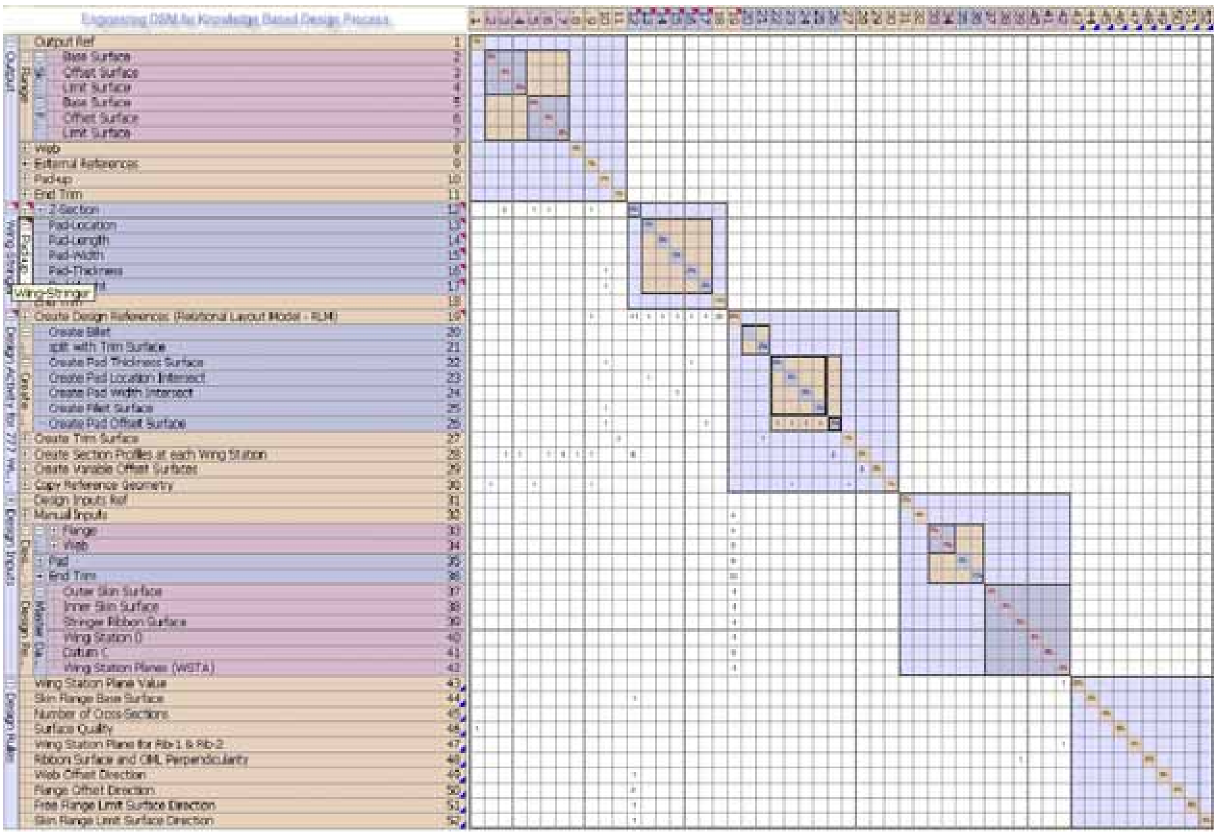

Figure 2. Sample engineering DSM for a knowledge based design process

An Engineering DSM captures and represents:

- Engineering design process
- Product structure and component hierarchy
- Design data flow
- Overall Design Process
- Geometry modelling process
- Design parameters
- Design rules
- Design object interdependencies

And a Software DSM (see Figure 3) elaborates on the Engineering DSM by capturing the implementation details at a greater depth which includes how the knowledge is represented in the system. Knowledge representation in a Software DSM is completely dependent on the underlying

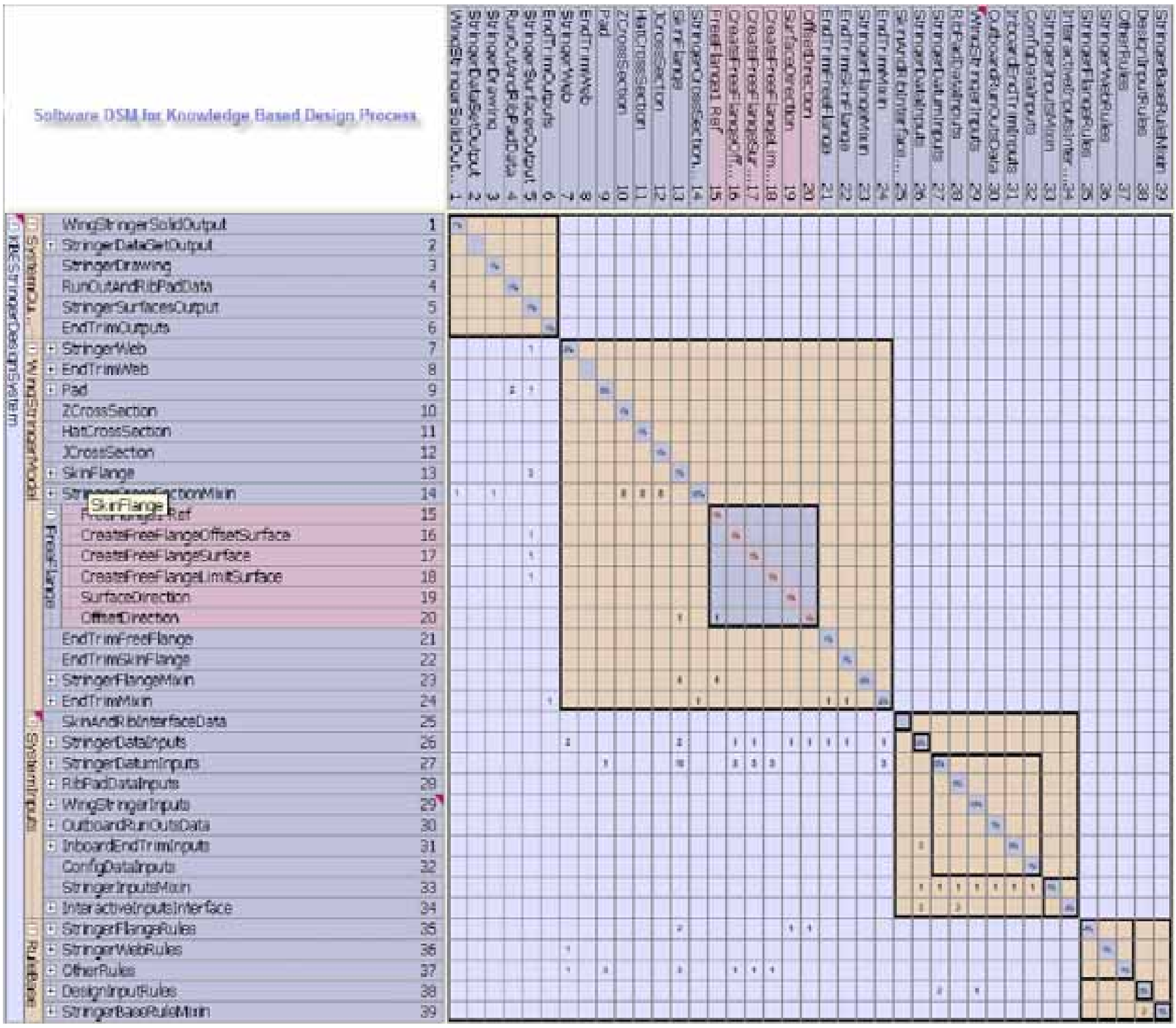

Figure 3. Corresponding software DSM for the engineering DSM in Figure 2

technology of the KBE system which is typically object oriented in nature. Software DSM eventually becomes the detailed architecture of the KBE system and makes it possible to track the application of rules and design parameters that are nuts and bolts of the design process. It also makes the system much more transparent and gives a clear cross sectional view at any point in the design process. Since there is a one on one mapping between Engineering DSM and Software DSM, impact analysis of a design change at requirements level or at a design parameter level can be easily tracked using DSM techniques.

2 CONCLUSION

A DSM based approach for capturing the product and process structure of a knowledge based design process is presented. This process identified and captured Engineering and Software specific knowledge associated to a KBE system at different levels of detail. The knowledge captured in these DSMs can be effectively used in design change management and impact analysis. Efficiency of this process is completely dependent on how well the Engineering DSM and Software DSM are generated. MOKA methodology is being used to effectively capture the informal and formal knowledge associated to a KBE application.

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DSM Based Approach for Managing Requirements, Rules and Design Parameters in Knowledge Based Design Process

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MANAGING COMPLEXITY
BY MODELLING DEPENDENCIES

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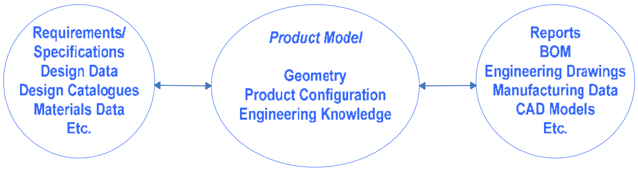
Knowledge Based Design Process

- Captures Design Knowledge at different stages of the design process
- Design knowledge includes a product model as well as a process model
- Typical inputs to the design process include:
  - User Requirements
  - System Specifications
  - Product data
  - Design rules
  - Standards
  - Geometry
  - Confuguration and
  - Engineering knowledge etc.



- Typical outputs are:
  - Overall product model
  - Reports
  - Drawings
  - CAD Models
  - BOM, Manufacturing data etc.

Knowledge Based Product Model

- Core of Knowledge Based Design Process
- Completely based on the domain knowledge
- Typically represented using Object Oriented Methodology
- Represents geometry, configuration and engineering knowledge as a library of:
  - Design objects,
  - Design parameters
  - Design rules and
  - Design procedures
- Creates a network of interdependent design objects
- Complexity increases as the product model grows in size
- Interaction with domain experts to create this knowledge model is a critical process
- MOKA (**M**ethodology and Tools **O**riented to **K**nowledge Based Engineering **A**pplications) methodology aids in capturing the design domain knowledge as an informal and formal knowledge

What is MOKA?

- MOKA (**M**ethodology and Tools **O**riented to **K**nowledge Based Engineering **A**pplications) uses Informal and Formal models to represent Engineering Knowledge
- Engineering knowledge is divided into:
  - Product Knowledge -- Knowledge about physical entity being designed
  - Process Knowledge -- Steps taken to design the Product
- Informal model is a structured, natural language representation of Engineering Knowledge
- Formal model is an object oriented representation of Engineering Knowledge and is captured using MOKA Modeling Language (MML)
- MML is an extension to UML and is specifically targeted for use in Knowledge Based Engineering
- More information on MOKA can be found at:
  - http://www.epistemics.co.uk/Notes/146-0-0.htm

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Engineering Change Management

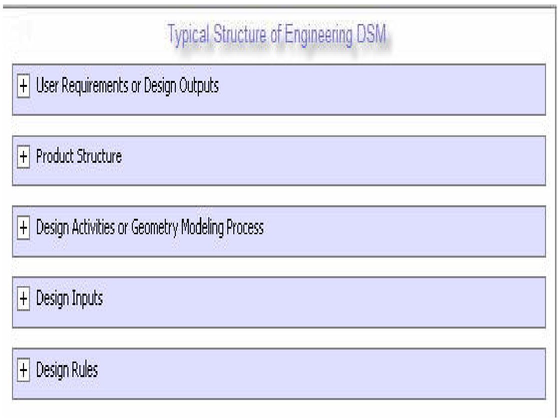
- Engineering design is iterative in nature
- Changes are part of every iteration
- Changes refine the design
- Engineering design changes and their impact are difficult to quantify
- Change review is a costly and complex process
- Engineering Design blended with software engineering multiplies the complexity of change management process
- A knowledge based design process is a combination of design and software engineering processes
- Changes in a knowledge based design process can occur in design domain and/or in software domain

DSM in Knowledge Based Design Process

- DSMs representing Engineering Design process (*Engineering DSM*) and a corresponding Software Design process (*Software DSM*) are defined using Lattix DSM tool
- Dependencies captured in DSMs enable the capture of design data flow
  - Flow of design inputs through the design process
  - Direct or indirect relation between given input and outputs, and vice versa
  - Origin and flow of design rules
  - Direct or indirect relation between a given rule and it's application to a design object or output, and vice versa
- Capture design object interdependencies and interfaces
- Identify the most critical or least critical data, rule, object or design procedure based on the usage
- Capture system, sub system and component hierarchy
- DSM techniques can be applied to understand, control and quantify the impact of Engineering design changes as well as in redesign

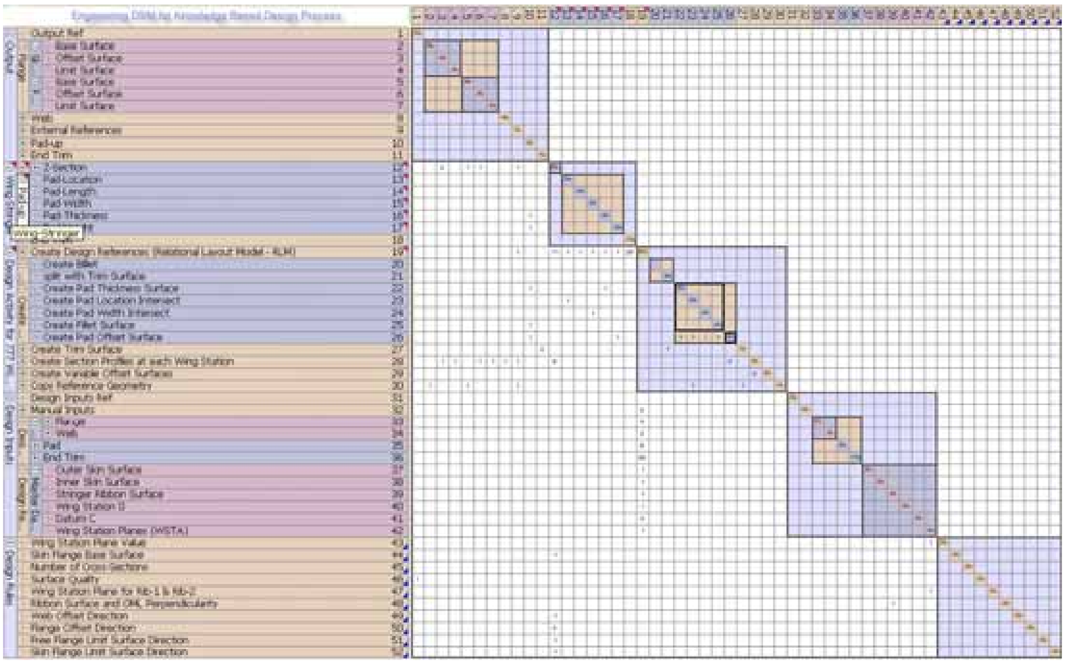
Engineering DSM

- Engineering DSM represents Engineering Design Process
- Captures product structure and component hierarchy
- Design data flow
- Design Process capture
- Geometry modeling process
- Design Parameters and Rules
- Interdependencies



- Generated mostly by design engineers and domain experts

Engineering DSM Sample



Software DSM

- Elaborates on Engineering DSM
- Representation is dependent on the underlying technology of the KBE system
- Object oriented in nature and modular in structure
- Typical structure has systems, sub systems, files, classes or design objects, design parameters, design procedures and rules
- Captures detailed architecture of the system
- Increases system transparency
- Enables cross section view of the system at any point
- Enables Engineering change management and impact analysis of:
    - ➢ User Requirements
    - ➢ System Specifications
    - ➢ Design Parameters
    - ➢ Design Rules etc.
- Generated mostly by domain experts and software engineers

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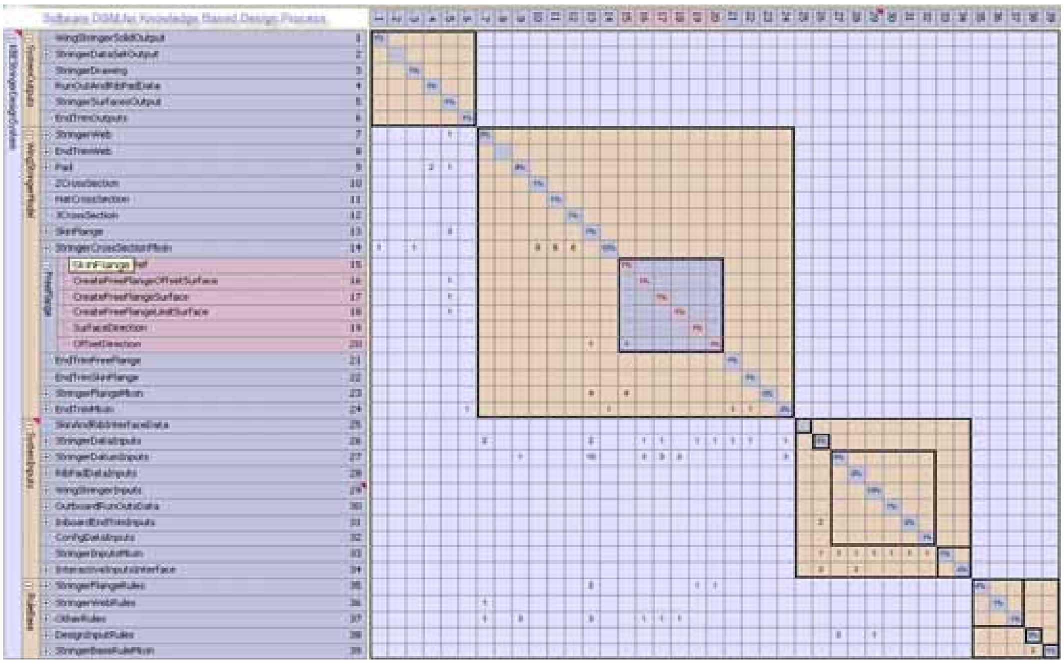
Corresponding Software DSM



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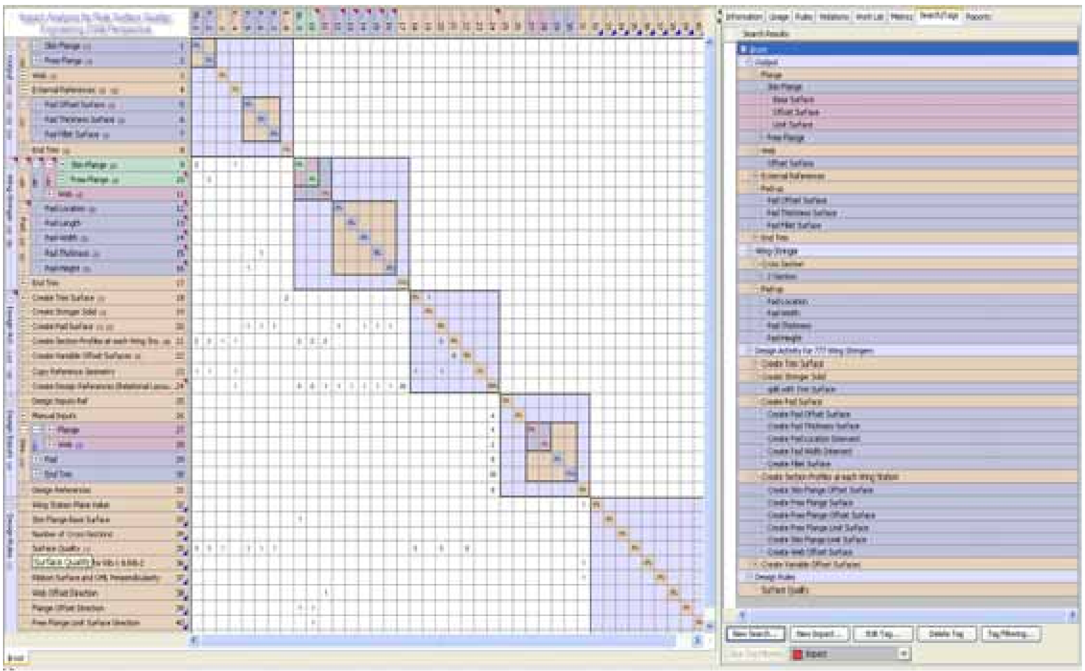
Impact of a Design Rule Change: Engineering DSM View



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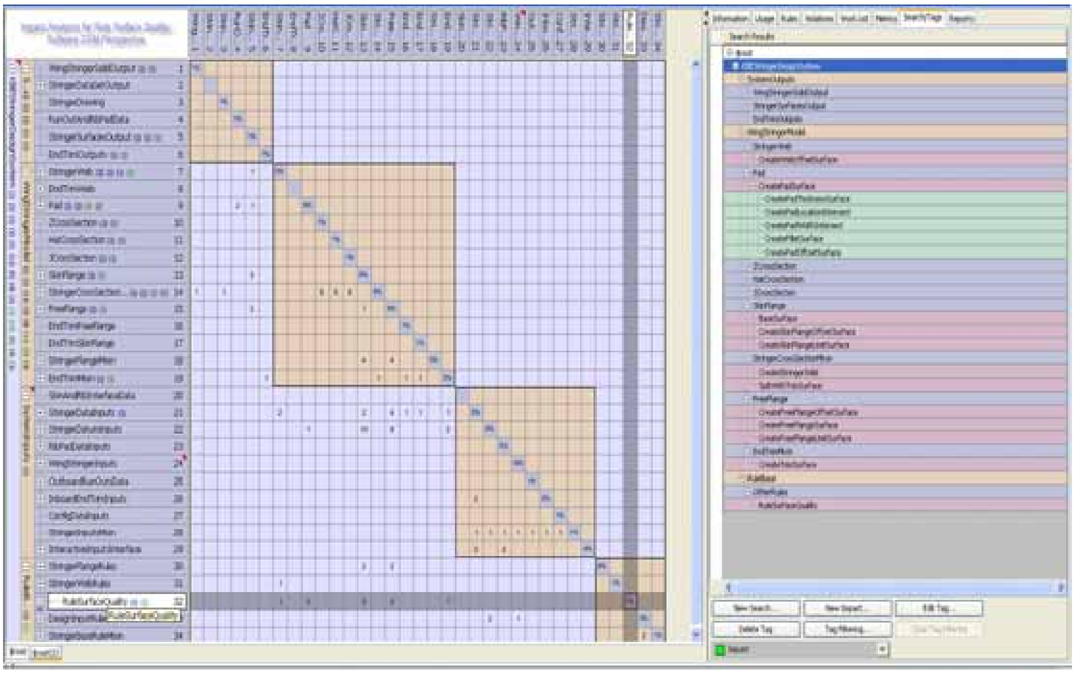
Impact of a Design Rule change: Software DSM View



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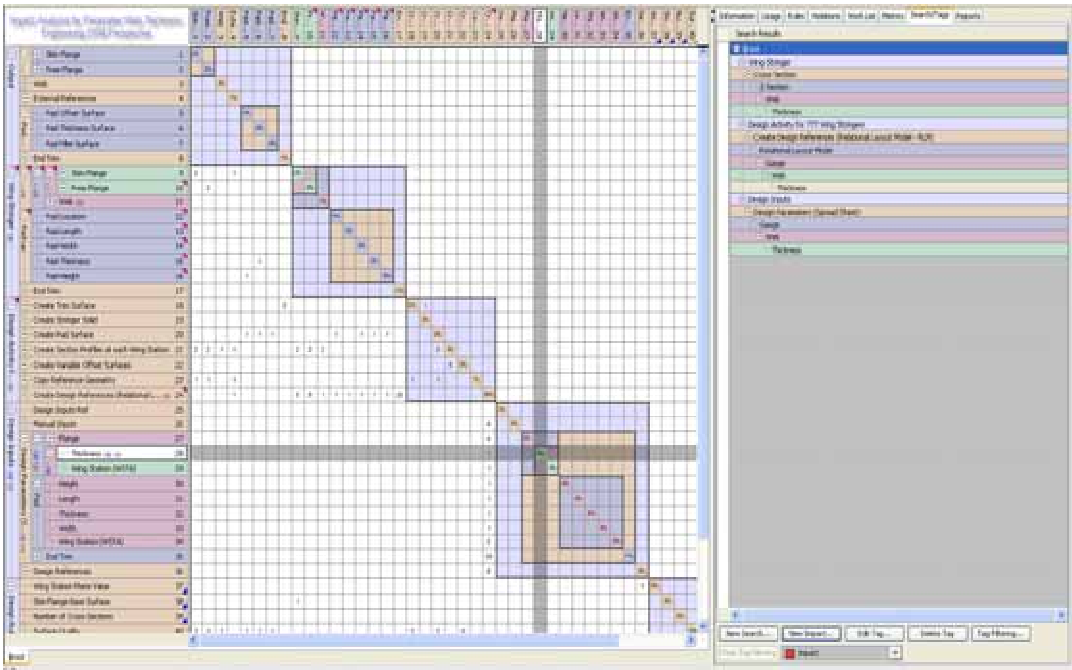
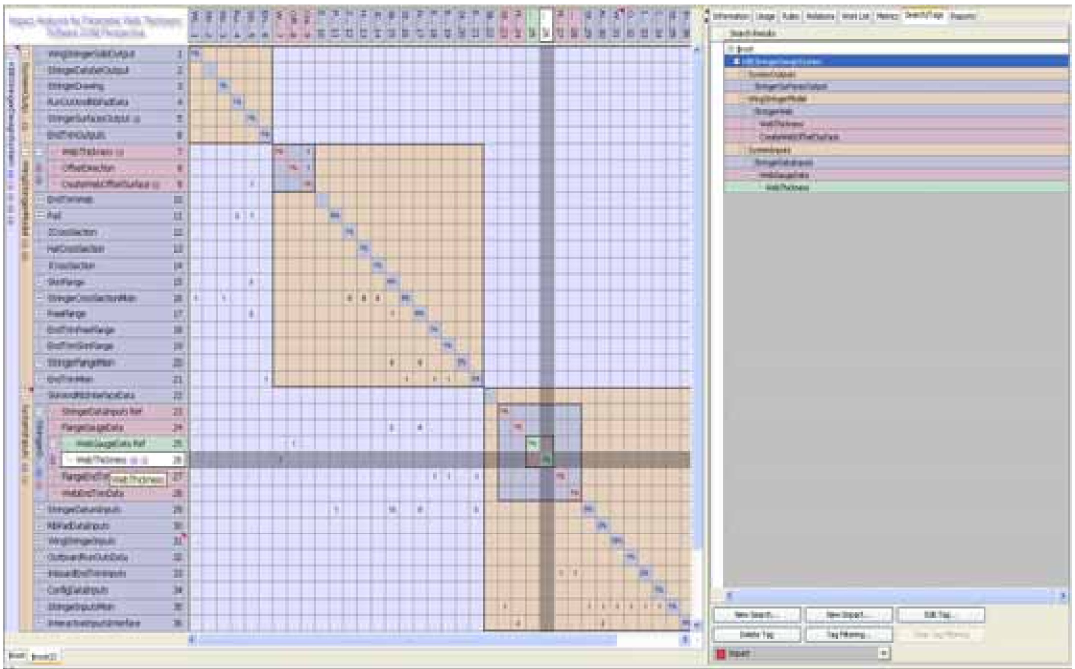
Impact of a Design Parameter change: Engineering DSM View



Impact of a Design Parameter Change: Software DSM View



Summary

- Application of DSM techniques to knowledge based design process is explored
- Engineering DSM and Software DSM are used as a means to capture Design and Software engineering knowledge respectively
- These are used to understand the overall knowledge based design process and in Engineering change management process
- These DSMs provide a single view for all the requirements, design inputs, rules, geometry modeling, product structure etc.
- It is always a challenge to capture the design knowledge of the domain
- MOKA is proposed as a knowledge capturing methodology