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Design Team Formation Using Multi-Objective Optimization and Solution Space Landscape Analysis

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1 Introduction

Recent advances in product intelligence, large-scale engineering systems, and interdisciplinary product development have significantly increased the complexity of design processes. In manufacturing industries, design modifications often propagate through multiple subsystems, resulting in costly iterations and rework. Simultaneously, organizations are required to manage increasingly sophisticated design capabilities while maintaining competitiveness in a rapidly changing market environment. Previous study (Oizumi and Aoyama, 2013) has proposed integrated product and organizational models that explicitly represent relationships among functional metrics, design parameters, capabilities, and human resources. Based on these models, communication requirements among design resources can be derived from product structures, enabling the generation of organizational structures intended to improve product functionality. However, existing approaches primarily focus on a single design objective and do not sufficiently address the trade-offs among multiple organizational requirements. Several studies have investigated capability-based team formation and organizational design problems in engineering design. For example, Kreimeyer et al. (2007) proposed a team composition method for improving collaboration between embodiment design and simulation departments based on relationships among engineering activities and competencies. However, such approaches do not explicitly address trade-offs among multiple organizational objectives.

In practice, organizational design must simultaneously consider conflicting objectives such as technical performance, organizational manageability, capability development, and responsibility allocation. Therefore, identifying a single optimal organizational structure is often insufficient for supporting managerial decision-making. To address this limitation, this study proposes a decision-support framework that combines multi-objective optimization with structural analysis of the solution space. Unlike conventional team formation studies that focus on identifying optimal organizational configurations, this study focuses on understanding the structural characteristics of organizational solution spaces through DSM-based landscape visualization.

2 Integrated Model of Product and Design Organization

The proposed method is based on an integrated model that represents both the product structure and the design organization structure (Oizumi and Aoyama, 2013). Figure 1 illustrates the integrated model used in this study. The product model consists of three domains: Functional Metrics, Components, and Design Parameters, while the design organization model consists of two domains: Capabilities and Design Resources. The integration of these domains enables the systematic derivation of organizational requirements from product architecture. The definitions of the product model and design organization model are summarized below.

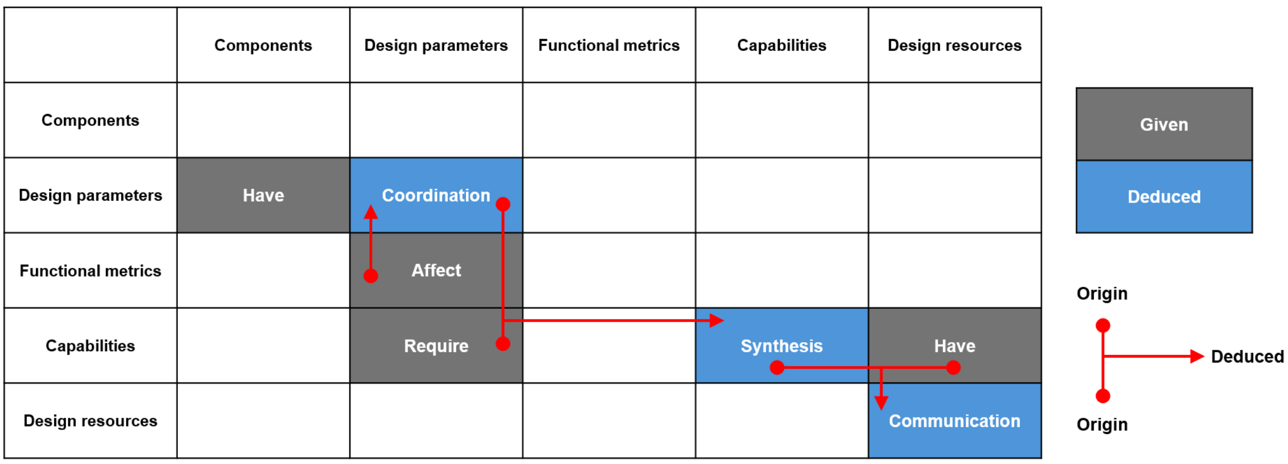

Figure 1. Integrated model of product and design organization depicted as multiple domain matrices

2.1 Product Model

The product model represents the target product using the following three domains.

- Functional Metrics: Performance measures used to evaluate product functionality, such as speed, efficiency, reliability, or other design objectives.
- Components: Physical subsystems or parts that constitute the product.
- Design Parameters: Engineering variables that designers can directly determine during the design process. Each design parameter belongs to a component and influences one or more functional metrics.

Relationships between functional metrics and design parameters describe how design decisions contribute to product performance. Through these relationships, coordination among design parameters can be identified.

2.2 Design Organization Model

The design organization model represents the organizational structure using the following two domains.

- Capabilities: Engineering knowledge and expertise required to determine specific design parameters.
- Design Resources: Individual engineers who possess one or more capabilities.

The model assumes that communication among design resources supports the synthesis of capabilities and facilitates knowledge sharing and capability development within the organization.

2.3 Integration of Product and Organization Models

The product model and the design organization model are integrated through explicit mappings between Design Parameters and Capabilities. Each capability is defined as the ability to determine one or more design parameters. Consequently, dependencies among design parameters can be translated into capability-level coordination requirements and eventually into communication requirements among design resources.

This integration provides a logical link between product architecture and organizational structure, enabling the evaluation and optimization of design organizations based on product requirements rather than solely on organizational considerations. The integrated model serves as the foundation of the proposed multi-objective design organization formation framework.

3 Proposed Method

The proposed method consists of two stages: (1) formulation of design team formation as multi-objective optimization problem and (2) acquisition of the landscape of the obtained design solution space.

3.1 Formulation of the Design Organization Formation as Multi-Objective Optimization Problem

The design organization formation problem is formulated as a multi-objective optimization problem. A candidate organizational structure is represented by communication among design resources, which are encoded as a Design Structure Matrix (DSM). The DSM is transformed into organizational units using grouping algorithms during the decoding process. The proposed method considers four objectives reflecting both product-development and organizational-management perspectives. By simultaneously optimizing following four objectives, the proposed method generates a diverse set of Pareto-optimal organizational alternatives that reflect different strategic priorities.

3.1.1 Improvement of Product Functionality

This objective evaluates the consistency between communication requirements derived from the functional metrics domain and the communication opportunities provided by the organizational structure. A higher value indicates that interactions required for coordinating design parameters for the purpose of improving functional metrics are more effectively supported by the organization.

3.1.2 Clarity of Component Responsibility

This objective measures the extent to which organizational units are specialized in specific product components. Higher values indicate clearer responsibility boundaries and facilitate efficient organizational responses to design changes and problem-solving activities. This objective is calculated in view of the component domain.

3.1.3 Organizational Manageability

This objective evaluates the balance of organizational-unit sizes. Uneven distributions of personnel may increase managerial workload and make organizational control difficult. Therefore, organizational structures with more balanced team sizes are preferred. This objective is calculated in view of the design resources domain itself

3.1.4 Future Organizational Capability

This objective evaluates the potential for long-term capability development within the organization. The metric considers opportunities for knowledge transfer and capability cultivation among design resources through sustained communication within organizational units. This objective is calculated in view of the capability domain.

3.2 Acquisition of the Landscape of the Design Solution Space

Rather than selecting a single optimal solution, the proposed method aims to provide decision-makers with insights into the characteristics of the entire solution space. Figure 2 illustrates the concept of solution-space landscape acquisition.

First, the obtained Pareto solutions are classified into regions according to their objective-function values. The multi-dimensional objective space is discretized into low-, medium-, and high-performance regions for each objective.

Next, the organizational structures contained in each region are aggregated. The DSMs corresponding to individual solutions are converted into network representations, where nodes represent design resources and links represent organizational relationships.

For each region, the frequency of occurrence of a relationship between two design resources is calculated from all solutions included in that region. The resulting frequency is visualized as the thickness of network links. Consequently, frequently observed relationships appear as thick links, whereas infrequent relationships appear as thin links.

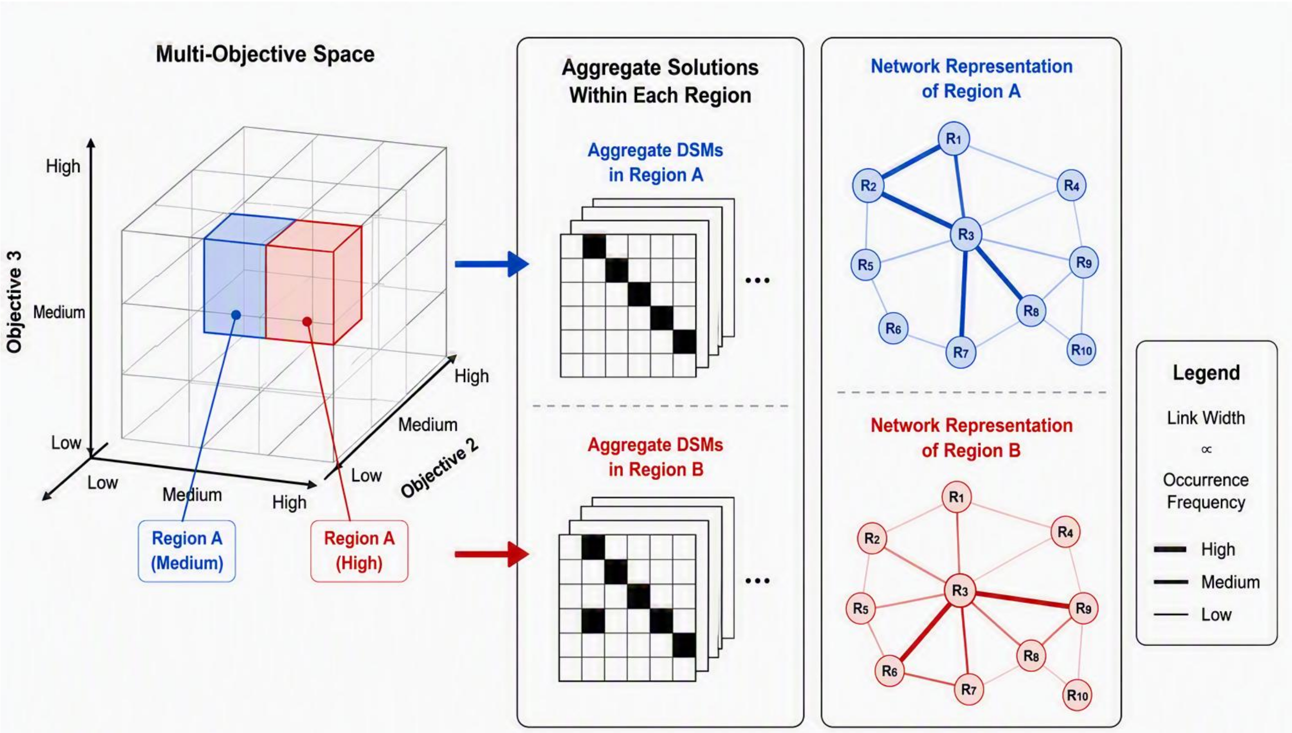

Figure 2. Acquisition of solution-space landscapes through network-based visualization of relationship frequencies

Comparisons between neighboring regions enable the identification of structural transformations associated with changes in values of the objectives. This visualization provides decision-makers with an intuitive understanding of which communication relationships are strengthened, weakened, formed, or eliminated when moving from one organizational strategy to another.

4 Case Study

4.1 Case Description

The proposed method was applied to a solar boat design problem previously used in design organization research (Oizumi and Aoyama, 2013). The product model consisted of 12 components, 27 design parameters, and 12 functional metrics, while the design organization model consisted of 10 design resources and 7 capabilities.

4.2 Visualization of Structural Changes Between Neighboring Regions

To support organizational decision-making, the obtained Pareto solution set was further analyzed using the proposed visualization method.

Figure 3 shows an example of structural transitions between neighboring regions of the solution space. In this example, the objective value of Clarity of Component Responsibility changes from a medium-performance region to a high-performance region, whereas the remaining objectives remain approximately unchanged.

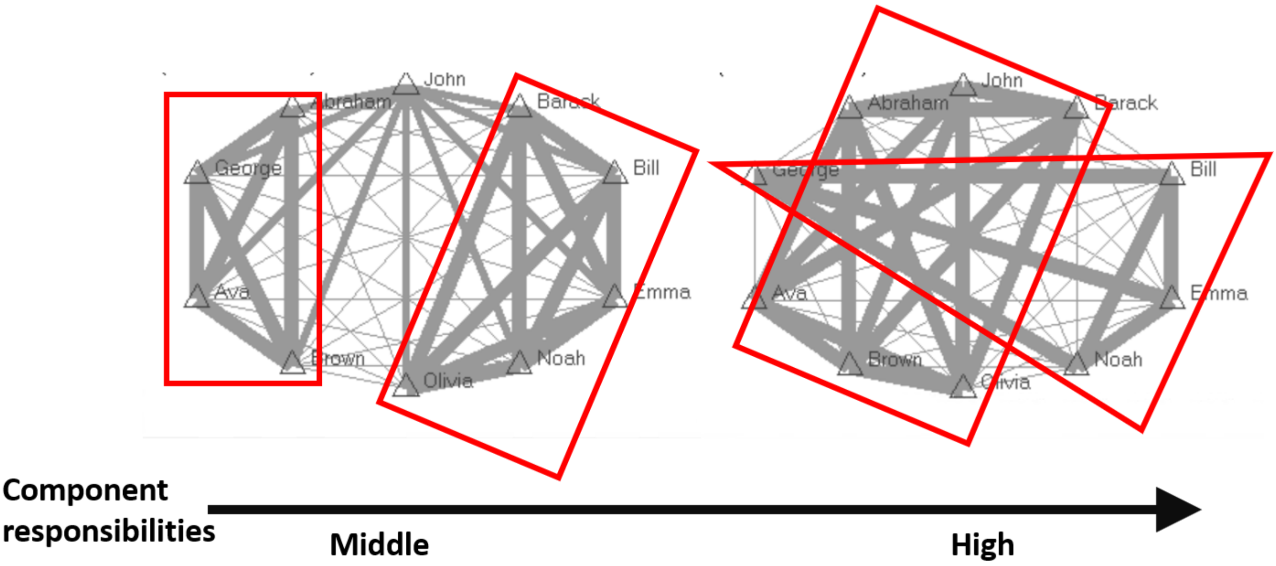

Figure 3. example of structural transitions between neighboring regions of the solution space

The comparison reveals that several organizational relationships disappear as component responsibilities become more clearly separated. At the same time, communication becomes concentrated around a smaller number of design resources, resulting in a more specialized organizational structure. Such structural transformations are difficult to identify solely from objective-function values but become explicit through network-based visualization.

These results demonstrate that the proposed method enables decision-makers to understand not only the existence of trade-offs among organizational objectives but also the specific structural changes responsible for those trade-offs.

5 Conclusion

This study proposed a decision-support method for design team formation based on multi-objective optimization and solution-space landscape analysis. The method integrates product and organizational models through explicit mappings between design parameters and capabilities, enabling organizational alternatives to be evaluated from both product and management perspectives.

The case study demonstrated that network-based landscape visualization can reveal structural transformations among organizational solutions that are difficult to identify solely from objective values. The proposed method provides decision-makers with interpretable insights into organizational trade-offs and supports strategic team formation in complex product development environments.

References

Kreimeyer, M., Deubzer, F., Danilovic, M., Fuchs, S.D., Herfeld, U., Lindemann, U., 2007. Team composition to enhance collaboration between embodiment design and simulation departments. Proceedings of the International Conference on Engineering Design (ICED 2007), Paris, France.

Oizumi, K., 2013. Design orchestration composer - A model base enabling holistic management of product, design process, and organization. Proceedings of the International Conference on Engineering Design (ICED 2013), Seoul, South Korea.

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