Product Platform Identification and Development for Mass Customization

George HUANG[1], **Sheng BIN**[1], **Gideon HALEVI**[2] (1)
[1] Department of Industrial and Manufacturing Systems Engineering, University of Hong Kong, China
[2] Technion, Faculty of Industrial Engineering and Management, Haifa, ISRAEL

Abstract
This paper is mainly concerned with the identification of an embryonic product platform from a family of products whose composition, configuration and characteristics are represented by Attributed Graphs. The problem becomes that of identifying the largest isomorphic sub-graph with the highest similarity. An algorithm is proposed for solving this problem together with several novel concepts.

Keywords:
Product Development, Design Theory, Product Platform

1. INTRODUCTION

New products are often evolved from past and existing products through multiple generations. Those design features that have proven successful or "fit" will survive and therefore be inherited by the new products, forming what is usually called a product "platform". This approach to new product development is coined as "Platform Product Development" by some leading researchers and management consultants [1] [2] [3]. Once established, the product platform provides a formidable foundation for agile product development and mass customization [4] [5].

Enterprise competitiveness is largely determined by speed, quality and cost of such evolution in response to diverse demands from mature customers. Whilst the platform approach has been practiced with successes in several industrial sectors, its industrial practice has remained as an art, heavily dependent on the experience and skills of individual designers and managers. Researchers and management consultants have been working on platform leveraging strategies, and guidelines for better structuring the approach to facilitate its adoption and implementation.

The need for scientific decision supports at the tactic level for design practitioners and managers has been widely recognized. Indeed, researchers have made enormous efforts. One of the common threads among several major projects [6] [7] has been to investigate if well-known Design Theory and Methodologies such as Axiomatic Design Theory [8] can be directly applied to solve problems in platform product development. Others attempt to devise new approaches and methods [9] [10] [11] [12]. While some progress has been made and the search continues, fundamental questions remain: (A) how a platform should be established for a family of products in a given industrial and market context, and (B) how a product development team chooses and then customizes the most appropriate product platform to meet the customer requirements from a specific market segment with particular manufacturing resources and supply bases?

2. PLATFORM PRODUCT DEVELOPMENT

This research is concerned with the development of decision supports to assist practitioners with platform product development activities. Two general approaches exist. One is the single-stage approach where the product platform and variants are optimized simultaneously [13]. The other is the two-stage approach with the first stage for developing a product platform for a family of products and the second stage for customizing individual variants from the platform.

2.1. Product Platform Development

This research adopts the two-stage PPD approach. This paper is related to the first stage of Product Platform Development while the second stage of Product Platform Customization has been discussed separately [14].

This first stage itself is very complicated. Several major steps have been identified, as shown in Figure 1, together with some major decisions associated with each step and potential/relevant methods suitable for the step. We have chosen to start with an initial embryonic platform concept and then gradually embody and refine the concept into a powerful platform. This paper is focused on the first step of Embryonic Product Platform Development.

2.2. Forward / Backward / Centre-Radiating

Product development has its lifecycles. Typical lifecycles include Functional Requirements in the Customer domain, Design Parameters in the Physical domain, Process Parameters in the Manufacturing domain [8]. Similar lifecycles can be observed for Platform Development.

Naturally, the development process starts with the front-end Customer domain, by examining the customer requirements for common market features and then classifying them into segments. The development proceeds to deploy the common customer requirements through common design parameters. This so-called "forward" approach has been adopted by several researchers [2] [3] [6].

	Title	Decisions	Potential Methods
1	Embryonic product platform development	▪ Identify common features among a family of products as the constructs of the initial platform embryo ▪ Classify preliminarily embryonic platform constructs	▪ Isomorphism algorithms for Attributed Graphs ▪ Matrix methods
2	Product platform embodiment	▪ Identify sensitivity of embryonic platform constructs in response to a set of given objectives ▪ Classify platform constructs into different categories e.g. Fixed, Fully Changeable, or Partially Changeable.	▪ Design of Experiments [12]
3	Product platform refinement	▪ Determine the optimum values for fixed constructs ▪ Determine the domains for changeable constructs	▪ "Design for X" ▪ Decision supports
4	Platform knowledge management	▪ Identify relationships between platform constructs ▪ Establish customization knowledge	▪ Constraint Management

Figure 1: Steps in platform development product.

In contrast, the development process may also start with examining the common features among the Process Parameters in the Manufacturing domain, and the common Design Parameters are then identified. PFA (Production Flow Analysis) [15] is a typical example of this so-called "backward" approach.

The third approach to Product Platform Development is what we call "Centre Radiating" adopted for this research. It starts with examining the Design Parameters of existing products and their components for physical commonality, which becomes the platform embryo for further embodiment and refinement forward and backward. Siddique [11] follows this "Centre Radiating" approach.

3. EMBRYONIC PRODUCT PLATFORM DEVELOPMENT

By following the "Centre-Radiating" approach, the primary objective of this first step is to identify a set of common elements among a family of products. This set becomes the initial elements of an embryonic product platform to be elaborated further to become a platform.

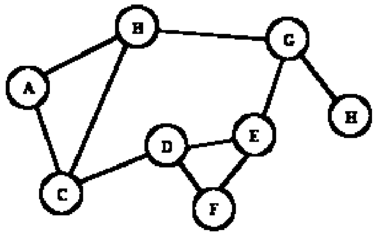

Figure 2: Attributed graph for a simple ball-point pen.

3.1. Graphs with Attributes of Multiple Viewpoints

Products are described in terms of their composition, configuration and characteristics. In this research, they are represented by a hierarchical BOM (Bills of Materials), graphs, and attributes respectively. Figure 2 is an example graph, representing the configuration of a simple ball-point pen. The hierarchical representation of the product composition is not necessary for this product due to its simplicity. All the components of the ball-point pen are described by certain parameters or key characteristics. They are attached to or embedded in the nodes as attributes.

The concept of viewpoints is introduced to group the attributes (key characteristics) with similarity by certain criteria. For example, the "Class Identity" viewpoint includes a few attributes, e.g. "Class" used to determine if comparison should be made.

3.2. Isomorphism and Clique Algorithms

The problem of identifying the common features among a group of products becomes the problem of identifying the largest common sub-graph(s) among the Attributed product graphs. There are two types of algorithms that are used for this purpose. One is to identify all the cliques among all the product graphs and then find the largest clique as the embryo platform. The other is to identify the largest isomorphic sub-graph as the embryonic platform.

However, most existing algorithms, clique or isomorphism, use exact match between elements of two graphs. Although some degree of compatibility may be included in the algorithms, similarity or differentiability measures are not usually considered. For example, Siddique [11] have used Graph Theory to identify isomorphic sub-graphs from a given set of product graphs that represent product structures.

Majority of isomorphism algorithms are for analysing only two graphs. The third graph is then analyzed together with the isomorphic sub-graph identified from the first two graphs. More graphs can be considered similarly. This type of pair-wise analysis is only possible with exact matching.

Step 1 - Represent Products with Attributed Graphs
- Composition
- Configuration
- Characteristics with Viewpoints

Step 2 – Construct Candidate Graphs

Step 3 – Evaluate Similarities
- 3.1 Evaluate Attribute Similarities
- 3.2 Evaluate Attribute Value Similarities
- 3.2 Evaluate Node Similarities

Step 4 – Identify Similarity Momentum Graphs
- 4.1 Evaluate Similarity Momentum for each Candidate Graph
- 4.2 Identify Momentum Graph
- 4.3 Evaluate Average Similarity Momentum

Step 5 - Identify embryonic platform
- Similarity Momentum Graph with the largest average similarity momentum

Step 6 - Classify the embryonic platform constructs for further consideration

Figure 3: Steps in embryonic platform development.

3.3. Isomorphism Algorithm with Similarity

Exact matching is unrealistic in embryonic platform development where only similar (c.f. exactly same) features are identified for further elaboration. It is essential to extend the Isomorphism Algorithm to consider such similarities. The incorporation of similarity consideration invalidates the pair-wise evaluation. A completely new algorithm is needed for this purpose.

Because of the combinatorial complexity, the efficiency of the extended algorithm has always been an important concern. Several versions of extensions have been experimented. The algorithm shown in Figure 3