Application Of Axiomatic Design to the Toaster Design
- A Case Study -

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This work is gratefully dedicated to my father Mohd Najib and my mother Norazizah Chin

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ABSTRACT

This project is preliminary project on application of axiomatic design concept to toaster design case study. The main objective of the project are to understand and able to use the Accalaro Designer version 2, improve the quality of functional of the product and to design are product by using the axiomatic design theory.

The project involves customer survey which carried out the information on the customers need. From the customers need information functional requirements FRs and design parameter DPs will be chosen. In result part, the objective to obtained uncoupled matrix design had successfully done. The basic principle of the axiomatic design theory are related to 4 domains which customer domain, functional domain, physical domain and process domain. The functional requirements FRs and design parameters DPs must significantly independent to each other.

Therefore, understanding of the axiomatic design will giving more advantage to designer in the design stage. The most important are the product design according to customers need and it is not over design by the designer.

ABSTRAK

Projek ini merupakan projek permulaan mengenai kajian kepada aplikasi reka bentuk axiomatik. Objektif utama projek ini adalah untuk memahami dan tahu menggunakan perisian rekabentuk Accalaro versi 2.0, meningkatkan kualiti fungsi roti pembakar dan mereka sesuatu produk dengan menggunakan rekabentuk axiomatik .

Projek ini melibatkan kajian kepada pelanggan dimana ia akan membawa maklumat mengenai keperluan pengguna. Daripada keperluan pengguna keperluan fungsi dan rekabentuk parameter akan dipilih. Di dalam bahagian keputusan, objektif untuk mencapai bentuk matriks yang tidak berpasangan telah berjaya dilakukan. Prinsip asas rekabentuk axiomatik adalah berkaitan dengan 4 bahagian, dimana bahagian pelanggan, bahagian fungsi, bahagian fizikal dan bahagian proses. Keperluan fungsi dan juga rekabentuk parameter mestilah dalam keadaan yang tidak bergantung sama yang lain.

Oleh itu, pemahaman kepada rekabentuk axiomatik akan memberikan kesan yang baik kepada pereka di dalam fasa mereka.Yang penting sekali adalah produk direka adalah bergantung kepada pengguna dan jangan mereka sesuatu produk tersebut sehingga ia terlebih reka kerana terlalu banyak fungsi.

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Introduction

1.1 General Overview Of Design

Design as a verb refers to the process of devising something. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process, in which the basic sciences and mathematics and engineering sciences are applied to convert resources to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. ***"Engineering design includes most of the following features: creativity, open-ended problems, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, production processes, concurrent engineering design, detailed system descriptions, and constraints such as economic factors, safety, reliability, aesthetics, ethics and social impact."*** – **[Adapted from ABET, 1990].**

Design implies decision-making. One major advantage with axiomatic design is that decisions are formalized using a well-understood pattern. Functional requirements (FRs) are first established. The design solutions, or design parameters (DPs), and finally process variables (PVs) are then determined. Design parameters DPs and process variables PVs may, in turn, have consequences and therefore have a need for supporting systems. For example, a combustion engine in a car needs, in terms of design parameters DPs, a cooling system, a starter, an ignition system, a muffler, and so forth. Consequences differ from constraints in that consequences can create constraints, functional requirements FRs, and design parameter DPs where as constraints are used for limiting the solution space when selecting a design parameter DP or a process variable PV. If consequences are identified, then the decomposition process is easier and more manageable Consequences of decisions made for design solutions as well as decisions made for designing processes are discussed in this thesis.

Designers typically follow these steps:

- Understand their customer's needs (requirements).
- Establish design objectives (specifications) to satisfy a given set of customer attributes.
- Define the problem they must solve to satisfy these needs.
- Create and select the solution through synthesis.
- Check (validate) the resulting design against the customer's needs.
- Implement the selected design.

The designer following the axiomatic design process

- Produces a detailed description of what functions the object is to perform.
- A description of the object that will realize those functions.
- A description of how this object will be produced.

1.1.1 General Axiomatic Design Concepts

Whether the design solution is a tangible product, service, software, process, or something else, designers typically follow these steps:

- Understand their customers' needs
- Define the problem they must solve to satisfy these needs
- Create and select a solution
- Analyze and optimize the proposed solution
- Check the resulting design against the customers needs

These are some of the benefits that are can produce from the implement of axiomatic design

- Independence axiom has helped to quickly identify the coupled design.
- Avoided changes in functional requirement FR throughout the design process.
- People know what they are discussing.
- Encourages creativity.
- Worked well for projects where clean-slate approach can be taken.

1.2 Background

Design is defined as the development and selection of a means (design parameters, or DPs) to satisfy objectives (functional requirements, or FRs), subject to constraints. Design is interplay between "what we want to achieve" and "how we want to achieve it."Axiomatic Design provides a framework for describing design objects which is consistent for all types of design problems and at all levels of detail. Thus, different designers can quickly understand the relationships between the intended functions of an object and the means by which they are achieved. Additionally, the design axioms provide a rational means for evaluating the quality of proposed designs, and guides designers to consider alternatives at all levels of detail by making choices between these alternatives more explicit. The main concepts of Axiomatic Design include the following:

(1) *domains*, which separate the functional and physical parts of the design.

(2) *hierarchies,* which categorize the progress of a design in the functional and physical domains from a systemic level to more detailed levels.

(3) *zigzagging,* which indicates that decisions made at one level of the hierarchy affect the problem statement at lower levels.

(4) *design axioms*, which dictate that the independence of the functional requirements must be maintained and that the information content (i.e. cost, complexity, etc.) must be minimized, in order to generate a design of good quality.

1.3 Axiomatic Design Technology

The technology of axiomatic design will reduce product development risk, reduce cost and speed time to market by all these

- Formalizing the conceptual design process into a continuous and measurable activity driven by requirements.
- Communicating the state of the design to all stakeholders at the earliest possible moment, well before traditional CAD documentation.
- Improving quality of design by analyzing and optimizing design architectures.
- Providing explicit traceability from Customer Needs to Requirements to Design Logic to Design.
- Clearly documenting and communicating the logical 'How and why' of a design, not just the 'What' of CAD documentation.
- Permitting design issues to be identified early and resolved without the cost of design-build-test-redesign cycles.
- Providing project management with the dependency structure of the design, enabling optimal scheduling and risk mitigation.

1.4 Objectives Of The Project

The objective of this project will feature a case study of the toaster in order to find functional requirements FRs and design parameters DPs and how to solve it in order by using axiomatic design method

- To design are product by using the axiomatic design theory.
- Using case study for getting information as a tool.
- Understand and able to use the Accalaro Designer version 2.
- Improve the quality of function of the product.

Chapter 2

Literature Review

In scientific research it is always important to study the work of others in the related field to understand the method employed. So that a better overall approach towards the implementation of research plan.

This chapter will review various work done before and currently, by others in axiomatic design and also information related to axiomatic design .

2.1 Axiomatic Design Process

Axiomatic design was developed by Nam Suh. There are four main concepts in axiomatic design - **domains, hierarchies, zigzagging, and design axioms**.

2.1.1 Domains

Design is defined as the development and selection of a means (DPs) to satisfy objectives (FRs), subject to constraints. Design problems can be divided into four domains. The number of domains remains constant at four, but the nature of the design elements in each domain changes depending on the field of the problem. The four domains may be generalized as the customer domain, the functional domain, the physical domain, and the process domain. These domains are shown in Figure 2.1. Associated with each domain are the design elements it contains. In the order listed, the elements associated with each domain are customer needs (CNs), functional requirements (FRs), design parameters (DPs), and process variables (PVs). In addition there are Constraints (Cs) which set bounds on acceptable solutions

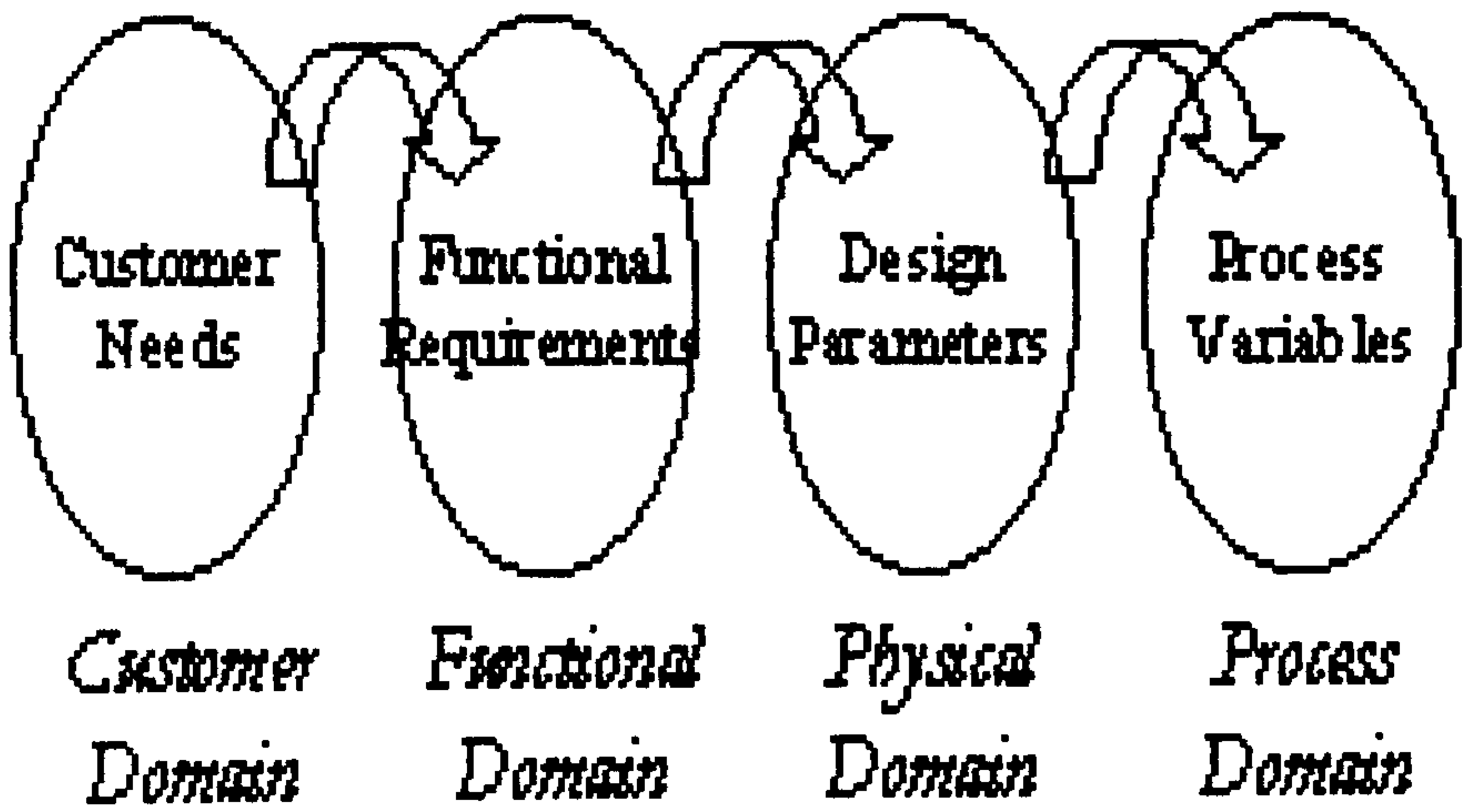

Figure 2.1 Domains of the Design World

The requirements specified in one domain are mapped in the design phases to a set of characteristic parameters in the table 2.1 on page 9.

Design phase	Design domain	Design element /phase activity
	Customer domain	Customer need (cn) benefit of customer seek
Concept design		customer's needs are identified and are stated in the form of required functionality of a product
	Functional domain	functional requirements (FRs) of the design solution additional constraints (Cs)
Product design		a design is synthesized to satisfy the required functionality
	Physical domain	design parameters (DPs) of the design solution
Process design		a plan is formulated to implement the design.
	Process domain	process variables (PVs)

Table 2.1 Domains represent in the table

2.1.2 Design Axiom

There are two design axioms about the relations that should exist between FRs and DPs which provide a rational basis for evaluation of proposed solution alternatives and the subsequent selection of the best alternative.

The approach is built around two axioms:

2.1.2.1 Axiom 1 - The Independence Axiom

In which it is stated that 'good' design occurs when the Functional Requirements (FRs) of the design are independent of each other. Considering the independence axiom, wanted a one-to-one relationship between functional requirements FRs and design parameters DPs. Ideally would want a square identity matrix. Practically it must compromise. The corollaries give direction to changes.

I. Corollary 1: Decoupling – should be attempted to decouple or separate different design elements. If done using the matrix method this would result in an identity matrix (or equivalent).

II. Corollary 2: Minimize FRs - If the designer can reduce the number of FRs it will simplify the design.

III. Corollary 3: Integrate Parts - When possible, without significantly compromising the other principles, we want to reduce the number of parts.

IV. Corollary 4: Standardization - Standardized parts tend to satisfy the design axioms, and should be used when possible to reduce the information content.

V. Corollary 5: Symmetry - When possible use symmetry to reduce the information content of the product.

VI. Corollary 6: Large Tolerances - Reduce the information content by using the largest tolerances possible.

VII. Corollary 7: Uncouple and Minimize Information - When possible the designer should strive to minimize information and interdependence between design components.

2.1.2.2 Axiom 2 - The Information Axiom

In which 'good' design is defined by achievement of minimum 'information' content (or. to grossly over-simplify the Axiom, good design corresponds to minimum complexity). The relationship between axiom1 and axiom 2 by look back what is stated in corollary 7, it states that there in an uncoupled whose information content it less than a given coupled design, it may appear that axiom 1 and axiom 2 are interrelated, thereby representing only one axiom. For example, one might that think that Axiom 1 is a consequence of Axiom 2, since an uncoupled design that obeys Axiom 1 has the minimum information content, compared with the coupled and decoupled designs. However, a closer examination reveals that it is wiser to keep these axioms as two independent propositions. For example, in the absence of Axiom1 one might choose a coupled design that happened to have less information than a particular uncoupled design, rather than to seek another uncoupled design having less information content (see corollary 7). Conversely, in the absence of Axiom 2, there is no way in which we can choose the best design among uncoupled designs satisfying Axiom 1. In an actual design process. One always starts out with Axiom 1 and seeks an uncoupled design. Only after several designs that satisfy Axiom 1 are proposed can we apply Axiom 2 to determine which the best among those proposed is. The ability to use Axiom 1 effectively is a hallmark of the creative designer.

2.1.3 Zig-Zagging

Zigzagging that describes the process of decomposing the design into hierarchies by alternating between pairs of domains.

2.1.3.1 Zig

- Conceptualize
- mapping FR=[DM]*DP
- Prove the Independence Axiom

2.1.3.2 Zag

- Define the FRs of the next level

The function and design parameter decomposition hierarchies in each domain represent it respectively. The decisions that are made at higher levels of the design hierarchies affect the statement of the design tasks at lower level. And moreover identifying functional requirements FRs at every level can be achieved only by identifying the corresponding design parameter DPs at that level. Instead of developing the FR hierarchy and DP hierarchy separately in each domain, they are developed through a zigzagging process between domains in axiomatic design. The Figure 2.2 can best illustrate zigzagging process.

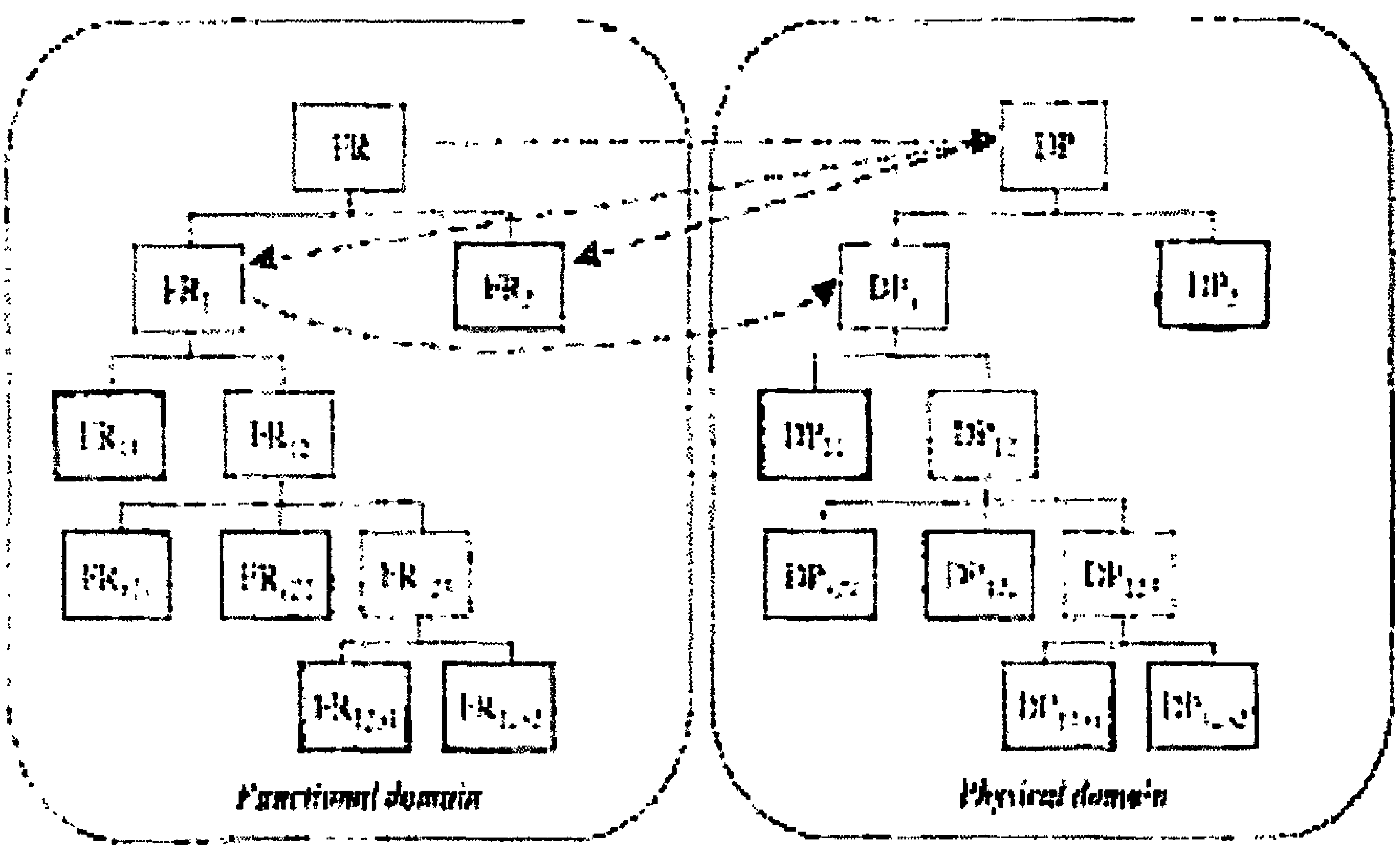

Fig 2.2 FRs and DPs decomposing by zigzagging

2.1.4 Hierarchies

The design process progresses from a system level to levels of more detail. It progresses from systems to subsystems to assemblies to parts to part features. This may be represented in terms of a design hierarchy. The decisions about the design object are structured in three of the domains in a hierarchical manner, and hierarchies exist for any design object in each of the domains: functional, physical, and process. Thus an FR hierarchy, a DP hierarchy, and a PV hierarchy exist for a design object. The information in the customer domain is an exception and cannot be structured as rigorously.

Domains, mapping, and hierarchies provide a structure for information about the design decisions that have been made. The framing of design tasks in this way enables the identification of regularities in design decisions.

2.1.4.1 Design Hierarchy

Design Hierarchies represented the design architecture. Beginning at the highest level, the designer selects a specific design by decomposing the highest-level FRs into lower-level FRs. This can be done once the highest level DPs are chosen. Decomposition proceeds layer by layer to ever lower levels until the design solution can be implemented. Through this decomposition process the designer establishes hierarchies of FRs, DPs and PVs. The output of each domain evolves from abstract concepts to detailed information in a top-down or hierarchical manner.