Abstract

The research describes a Virtual Visualization Strategy to enhance product value in an intensely competitive market. As products reach maturity, they become more similar in the range of functions that they provide. This leads to competition via reduced retail price and ultimately reduced profitability. A competitive design strategy is therefore needed that can produce higher value products. An Enhanced Value Experience has been identified that can assist designers to provide quality products and to give them a unique positioning. On the basis of this value opportunity, a Virtual Visualization Strategy has been formulated and applied to the domain of retail furniture. Through this, customers can create their own personalized products.

The Virtual Visualization Strategy incorporates four functional layers: (1) key technique layer, (2) integration and communication layer, (3) experience layer, and (4) decision making layer. First, the key technique layer serves as the core of interactive product design, including intuitive 3D transformation, compatible design, and virtual development plane. Second, the integration and communication layer consists of the entire digital components of the Virtual Visualization Strategy, including the 3D database of product modules, the 3D environment modules, the audio/video modules, the interface modules, and the interactive behavior modules. Third, the experience layer integrates the value experience of customer involvement, differentiated product appearance, environment interaction, and variety seeking. Finally, the decision making layer allows the customer to find their own personalized products.

During this project, six patents for the prototype database were successfully applied for. This provides support for the theoretical viability of the Virtual Visualization Strategy. It now remains to be further developed and tested in the real marketplace.
Acknowledgements

I am eternally grateful for the help of the people listed here. First I would like to thank my principal supervisor, Professor Allan Whitfield, for having the patience and understanding to work with me in this endeavour. Without his support, advice, and guidance, the design research could not have been completed. I would also like to thank Mr. Lotars Ginters, for his advice and help throughout my experience whilst studying for the Doctor of Design. His thoughtful advice has helped me to reach this point. Also, thanks to all staff members and friends at the National Institute of Design. With their recommendations and assistance, I have been given the needed resources to complete this design thesis.

In Taiwan, heartfelt thanks to Professor Ming Chyuan Ho and Associate Professor Chi Hsiung Chen for the collaboration opportunities to work on the 2008 Creative Furniture Design project. Thanks also to the Staff members in the Intellectual Property Office, Ministry of Economic Affairs of Taiwan for assisting with the Design Patents application matters. A special thanks to Professor Shu Hsiang Hsu, President of Transworld Institute of Technology, for giving me much needed encouragement, financial support and administrative assistance during this design research.

Most important of all, I would like to thank my family for their unconditional love and support. Thanks to my wife Ya Wen for her patience and understanding so that I could devote myself to this overseas research. Therefore, this design research is dedicated to my wife and my son Kuan Yi. With their support the completion of this project has been made possible. Finally, my thanks to God.
Declaration

I certify that the thesis entitled: A Virtual Visualization Strategy for the Creation of Personalized Products submitted for the degree of: Professional Doctorate in Design is the result of my own research, except where otherwise acknowledged, and that this thesis in whole or in part has not been accepted for an award, including a higher degree, or any other university or institution.

Full Name: DAWEI LIN

Signed……………………………………… Date ………………………………………
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   University, Taiwan, pp. 308-317
Design Patents

Design patents to protect the intellectual property of the furniture prototype database for three Zen chairs and one tea chair have been applied for and were approved by the Intellectual Property Office of the Ministry of Economic Affairs, Taiwan in December 2005. An addition of two desks was approved in February 2006.
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Design Patent: Zen Chair
Application No: 094300410
Approval Date: 6 December 2005
Design Patent: Zen Chair
Application No: 094300411
Approval Date: 6 December 2005
Design Patent: Tea Chair
Application No: 094300412
Approval Date: 6 December 2005
Design Patent: Desk
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## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Projection</td>
<td>One of the display methods of Virtual Reality. Viewers do not need to wear any special equipment to view the 3D images.</td>
</tr>
<tr>
<td>Behavior</td>
<td>A Behavior is expressed as a script - the visual representation of a behavior, applied to an element, as represented in the Schematic.</td>
</tr>
<tr>
<td>Bezier Progression</td>
<td>Interpolates a float according to a 2D bezier curve in the [Min, Max] range, in a given number of milliseconds.</td>
</tr>
<tr>
<td>Broadcast Message</td>
<td>Sends a message to every object waiting for it.</td>
</tr>
<tr>
<td>Building Block</td>
<td>A Building Block (BB) is the fundamental element within Virtools, BBs encapsulate a specific task. BBs are a visual representation of a software element known as a function.</td>
</tr>
<tr>
<td>Cave Virtual Reality</td>
<td>One of the display methods of Virtual Reality, the cave participant wears liquid crystal shutter glasses while images are projected on the wall.</td>
</tr>
<tr>
<td>Character Curve</td>
<td>Makes a character follow a 3D curve.</td>
</tr>
<tr>
<td>Follow</td>
<td></td>
</tr>
<tr>
<td>Disruptive Innovation</td>
<td>When a company uses a new technology to disrupt the prevailing business model in an existing market that is filled with overserved customers.</td>
</tr>
</tbody>
</table>
**Grid Path Solver**  Solve a new path finding problem.

**Immersion Virtual Reality**  The display of Virtual Reality with a head mounted display (HMD); the monitors are placed very close to the eyes giving a field of view which may extend to 90 degrees.

**Interactive 3D**  Interactive 3D is the creation of 3D models and worlds that can be controlled by the user and that react to events that happen in those worlds. It is the basis for creating Virtual Reality Environments: simulated realities that attempt to duplicate, alter or enhance the real world.

**Mature Product**  When products reach the stage of market maturity and saturation. Manufacturers attempt to extend the period by introducing a stream of new products or modifying them to bring them back through the life cycle.

**Module**  The concept of separating a system into independent parts, common sub-assemblies or compositions, which can be treated as design unit.

**Multiplication**  A mathematical operation, to add a parameter to itself a particular number of times

**New Market Innovation**  When a company discovers that people are struggling to get a job done on their own because no suitable products exist, and creates a product or service that enables customers to get that job done faster and cheaper than ever before.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Object Slider</strong></td>
<td>Impedes the camera viewpoint and character from penetrating a 3D object in the specified group.</td>
</tr>
<tr>
<td><strong>Operational Innovation</strong></td>
<td>When a company discovers inefficiencies in a business operation and works to address those inefficiencies through creative solutions.</td>
</tr>
<tr>
<td><strong>Per Second</strong></td>
<td>Calculates a progression (Y) according to a given speed (X): ( Y = X \times \text{Elapsed Time during one frame} ). X can be any kind of parameter as far as this parameter is only made of float values.</td>
</tr>
<tr>
<td><strong>Planar Reflection</strong></td>
<td>Creates a reflection on a plane of objects in a group.</td>
</tr>
<tr>
<td><strong>Poser</strong></td>
<td>A figure generation program by E Frontier America Inc.</td>
</tr>
<tr>
<td><strong>Product Family</strong></td>
<td>Consists of family members which share a common product platform and targets one or multiple market segments.</td>
</tr>
<tr>
<td><strong>Product Innovation</strong></td>
<td>A company adopts new design concepts or technology to create new products or services that are better than existing ones.</td>
</tr>
<tr>
<td><strong>Product Opportunity</strong></td>
<td>The most common type of innovation, resulting from improvements that are made to existing products and services. A product opportunity exists when there is a gap between what is currently in the market and the possibility for new or significantly improved products that result from emerging trends.</td>
</tr>
</tbody>
</table>
**Product Platform**  
A common product core from which a product family is efficiently developed and produced. Each family member is realized by adding a set of member specific features to the core. It combines the most representative attributes of a category.

**Psychographic**  
This segmentation divides the market into groups based on social class, lifestyle and personality characteristics. It is based on the assumption that the types of products an individual purchases will reflect that person’s characteristics and patterns of living.

**Remove Mesh**  
Removes a mesh from the selected 3D object.

**Schematic**  
The Schematic is used to view, edit and debug scripts within Virtools Dev. A script is simply a visual representation of a behavior attached to a behavioral object.

**Select Mesh**  
Selects which mesh should be used to represent the 3D object.

**Set Orientation**  
Sets the orientation of a 3D object.

**Set Texture**  
Sets the texture of a material.

**Static Model**  
A prototype of product that can not experience its aesthetic appearance by intuitive 3D transformation
**Switch on Key**    Activates the appropriate output when receiving a Key.

**Timer**    Waits for a given time to have elapsed.

**Translate**    Moves a 3D object.

**Unlimited Controller**    Controls a character by using animations played in response to messages.

**Virtools Dev**    One of the interactive 3D software created by Virtools company.

**Wait Message**    A behavior object awaits the receipt of a message.

**Web 3D**    One of the display methods of Virtual Reality, the display of 3D images and interaction through the internet.
The challenges of a mature market are highlighted by market saturation and reduced profit margins. Typically, rival companies offer similar products and services, and compete primarily on the basis of price. In such an environment, new product development becomes critical. This entails not only the identification of new products, but also the related logistics of speed to market, quality and cost of production (Lau et al. 2003). Furthermore, contemporary customers are more discerning than those of the pre-digital era (Noble et al. 2005). Before making a purchase decision, customers can access information through multi-channel media, and evaluate products based on their benefits and price. Globalization has further compounded the difficulties and resulted in more intense market competition (Craig & Douglas 1996; Amato & Wilder 2004). An expanding range of products and services is now available to individuals, with rare exceptions such as the recent launch of the iPod. We have entered a buyer’s market.

This research project offers a new product concept and its realization as a working prototype. It does so via a design strategy (Virtual Visualization Strategy) that addresses the following questions:

1. How can a value opportunity be identified that is capable of revitalizing mature products in an intensely competitive market?
2. How can a design strategy be formulated that makes the competition irrelevant?
3. How can marketing, design, and state-of-the-art technology be integrated to deliver new products in a highly competitive market?
(4) What is the appropriate presentation method for meeting individual customers’ requirements?

The vehicle for this research is the design of domestic furniture, whereby customers can create their own furniture and order it online via the internet and subsequently can have it delivered to them.

1.1 Design Strategy Criteria

(1) How can a value opportunity be identified that is capable of revitalizing mature products in an intensely competitive market?
A mature product is characterized by both low profit margins and similar quality that needs revitalizing to extend its life span (Hisrich & Peters 1991; Vasconcellos 2002). New product development should offer competitive value to individual customers for unique market positioning.

(2) How can a design strategy be formulated that makes the competition irrelevant?
Without patent protection, existing designs can be easily imitated. An effective market approach is the ‘Blue Ocean Strategy’. It stresses the importance of unique positioning in which an uncontested market is created that makes competition irrelevant (Kim & Mauborgne 2005). A company can create, via this approach, a product that possesses unique features, and so avoid competing on price with its competitors. Accordingly, a corresponding design strategy that incorporates these advantages is necessary.

(3) How can marketing, design, and state-of-the-art technology be integrated to deliver a highly competitive new product?
Once the new design strategy has been formulated, the challenge is to integrate all of the design elements with state-of-the-art technology. ‘Interactive 3D’ technology (Johnson et al. 1976; Kanev & Sugiyama 1998; Theis et al. 2006) offers a potential visualization medium with many virtual reality applications. It has considerable advantages for new product development.

(4) What is the appropriate presentation method for meeting individual customers’ requirements?
A platform is required that facilitates interaction between the customer, the products and the environment. This must offer appropriate information to facilitate a purchasing decision.

The research described in this thesis proposes a Virtual Visualization Strategy to assist designers in offering enhanced value products for individual customers through integrating product design, marketing and state-of-the-art technology. To achieve this, design techniques involving intuitive 3D transformation and the virtual development plane have been developed. These have been located within a virtual platform that offers an environment to assist users (potential customers) in their furniture selection decisions on the internet.

Underpinning the above is the development of a ‘technological innovation method’ (Wang 1998) entitled Virtual Visualization Strategy. This incorporates four functional layers: the key technique layer, the integration and communication layer, the experience layer, and the decision making layer. Each contains different functional elements. The discussion focus is on the first two layers. First, the key technique layer consists of intuitive 3D transformation, compatible design and the virtual development plane. Intuitive 3D transformation makes virtual visualization possible by interchanging 3D product modules. Compatibility of design components ensures the feasibility of all possibilities. This is achieved through a virtual sifting
A Virtual Visualization Strategy for the Creation of Personalized Products

Figure 1.1 Methodology of the Virtual Visualization Strategy
mechanism. The virtual development plane serves as a reference plane for product modules. It allows for an interchange in positioning to propagate all potential design variations without an increase in cost.

Second, the integration and communication layer exploits advanced multimedia interactive 3D which serves as a marketing platform. It integrates all components of the Virtual Visualization Strategy, such as the 3D database of product modules, 3D environment modules, audio/video modules, interactive behavior modules, and interface modules. Once these components have been built, the Enhanced Value Experience can be presented. Figure 1.1 illustrates the relationship between the different functional layers of the Virtual Visualization Strategy. Each of them serves as a different functional segment.

1.2 Research Structure

Chapter One serves as an introduction. Chapter Two provides an overview of academic and professional literature related to product development. Chapter Three identifies the Enhanced Value Experiences. This allows for the development of unique products that existing competitors cannot offer. It also offers a methodology for creating enhanced value in a competitive market. Chapter Four focuses on the application of the Virtual Visualization Strategy to Chinese furniture. Two product families are identified and a 3D database of furniture modules is constructed. Chapter Five covers the integration of virtual visualization components and opportunities for customer interaction on the internet. Finally, Chapter Six summarizes the results of the research and indicates avenues for future research.
Chapter 2 Background

This thesis presents a Virtual Visualization Strategy for the creation of personalized products. This chapter discusses the research problems, research background and relevant literature. It commences with an overview of demand pull and supply push market theory and how unsatisfied demand can be addressed.

2.1 Evolution of the Product Market

The shaping of a market economy is based on the relationship between supply and demand. Geroski (2003) states that the primary reasons for innovations are demand pull and supply push. The demand pull arises from human needs. As companies recognize these demands, they develop products and services to satisfy them. As companies penetrate the latent needs of the customer, they develop further new products and services to stimulate customers’ potential needs. The emergence of such products incorporate innovations. There are four types of innovation that companies can adopt: (1) product or service innovation, (2) new market innovation, (3) operational innovation, and (4) disruptive innovation (Ulwick 2005). From a supply and demand perspective, the evolution in the product market can be categorized into four periods. They are, demand exceeding supply (1850-1950), supply exceeding demand (1951-1990), supply equalling demand (1991-2000), and potential demand exceeding supply (2001 onwards) (Cagan & Vogel 2002). Table 2.1 illustrates the evolution of the product market from the supply and demand perspective.
2.1.1 The Period of Demand Exceeding Supply (1850-1950)

This period is characterized by higher demand than the market can satisfy. From 1850 to 1950, the production methods were largely craft-based and gradually shifted to machine mass production. Skill was all important: craftsmen turned raw materials into handiwork using tools and experience (Pine 1993). However, the inefficiency of craft-based techniques could not satisfy the growing demand of a mass market. The Industrial Revolution gradually replaced hand-tools with machinery, and mechanization became the primary means of production. During this period, the challenge was to manufacture products in large quantities at low cost to satisfy the growing market demand, instead of making things ‘pleasing to the eye’ or even easy to use. In this period, the products mainly satisfied users’ practical needs. Another characteristic for this period was that production drove consumption. Manufacturers offered limited products in the market and a product’s value was based upon its functionalities. The products served as an extension of customers’ needs to achieve specific tasks in the environment where they lived.
2.1.2 The Period of Supply Exceeding Demand (1951-1990)

Advanced technology improved industrial productivity and allowed manufacturers to produce products in large quantities. This resulted in an increasingly competitive marketplace. The focus on functional features gradually shifted to usability. Products became differentiated in terms of size, model, color, and packaging, enabling the development of more target markets. Foxall and Goldsmith (1994) argue that in such a competitive market, companies tended to focus upon increasing productivity and cutting production costs. They also attempted to revitalize products by repositioning them for new markets through redevelopment and improvements.

In mass production, value was seen as the services or features a product provided for the best price. Good value was based on the lowest cost with the greatest number of features. The objective of the company was to keep costs low, profit moderate, and to sell in large quantities. As a result, increases in the number of competitors in the globalized world created excessive supply over demand.

2.1.3 The Period of Supply Equaling Demand (1991-2000)

The objective in this period was to offer personalized products or services with more customer appeal. This period was characterized by the pursuit of a supply and demand equilibrium, in which many companies attempted to provide customized products for individual customers. It was partly the result of mass production through high productivity, low cost, consistent quality and fast response to market changes (Westbrook & Williamson 1993; Jiao et al. 1998; Duray et al. 2000). Pine (1993) states that companies made use of increasing mass customization that allowed customers to personalize their desired products in a saturated market.
Manufacturers made various products that addressed customers' preferences for each product life cycle. In this period, the digital revolution enabled companies to offer more products and services and to distribute them globally. The emergence of mass customization reflected customers’ differences in interests, behavior, personality and lifestyle. In addition, advanced technology and production capabilities accelerated personalized services (MacCarthy et al. 2002). Companies became more responsive to customers and incorporated customer insights into their design process. They built appropriate products for individual customers that mass production previously had been unable to.

2.1.4 The Period of Potential Demand Exceeding Supply (2001 onwards)

The beginning of the 21st century can be defined as the period of potential demand exceeding supply. Potential demands are those unsatisfied human desires that need to be fulfilled. Manning and Reece (2004) argue that four dimensions make up the *total product*: the generic product, the expected product, the value-added product, and the potential product. The first three products can be achieved via product development and marketing strategy. The fourth, however, potential product, is related to the evolving human needs that designers should consider in their prospective products. To reach beyond existing demand and to look into the future, Kim and Mauborgne (2005) stress that companies should focus on potential positioning to achieve greater customer loyalty. To find such potential human needs becomes the key to offering competitive quality. From a product development perspective, Kapoor (2001) states that futuristic design based on fantasy leads to product development that would not normally occur.

The concept of fantasy is derived primarily from entertainment, such as theme parks, and 3D games, plays and concerts, and movies and television shows.
Cagan and Vogel (2002) argue that we are in a fantasy era and that customers now hunger to satisfy their dreamlike ‘fantasy’ desires. The concept of fantasy highlights the vision underlying this potential demand that needs to be realized. Companies need to envisage the possibilities when a product transforms into a ‘mediator’ that embodies fantasy. What will it be? Companies can stage an experience whenever they engage customers, connecting with them in a personal and memorable way (Schmitt 1999). However, existing product development lacks this new vision.

2.2 The Mature Product in the 21st Century

We are in the fantasy era (Cagan & Vogel 2002; Plunz 2002). Fantasy is characterized by the connection inherent in a future dream world. As people have satisfied their physical and social needs, they now search for spiritual contents and future visions. This search for future visions corresponds to the need for self-realization. In a dream world of future visions, any possibilities and variations can emerge. For instance, Nike’s slogan now is ‘nothing is impossible’. Kapoor (2001) stresses that in any future vision customers look to build a world that is more humane, precise, peaceful and attractive.

Fantasy is one of the drivers for innovation without limitation, whereby a novelist of science fiction depicts future worlds, the space age and even fairy tales. Artists and movie makers further visualize the script. Many innovations are based on the predictions of the fantasy world, such as virtual reality, space exploration, and even gene duplication. Fantasy not only benefits literature and art, but is also advantageous for invention and design.

As we move into the 21st century, products in an intensely competitive market remain to be revitalized. A mature market is saturated with similar products that
sell at comparable prices. As a result, demand for further functionality and usability is decreasing. Customers now desire products with higher value and quality that address their upper level needs such as self-realization. Hisrich and Peters (1991) state that products require appropriate strategies for different marketing problems and challenges within the product life cycle. During the mature stage product development should be conducted with distinct strategies to enhance customers’ satisfaction.

As digital communications technology has become more widespread, companies have found it more difficult to compete on price alone. Providers now need to offer unique products or services that no one else provides, or offer them in a unique way. In the digital marketing environment, the customer can be closely involved in the creation of any product or service. Therefore, designers need to develop products that are competitive with new personalized capabilities, rather than offering a general product. In short, the digital era has highlighted the connection between design development and possibilities in addressing the customers’ unlimited upper level needs.

2.2.1 Integrated Product Development

Traditionally, the product development process focused on marketing, design and engineering separately. However, this separated process created difficulties for a company to offer competitive products to customers. An integrated product development is required. Andreasen and Hein (1987) stress that integrated product development is a good model for marketing, product design and production. The integrated model benefits from different disciplines including design, engineering, and market research in creating a higher value product that is useful, usable, and desirable to the users (Cagan & Vogel 2002). However, there is an added challenge
for product designers to achieve higher product value in this fantasy era. Apart from focusing on product development, product designers also need to utilize state-of-the-art media to explore possibilities in product design and communication with customers (Shen 2005). State-of-the-art media offer the opportunity to connect with potentially unlimited possibilities. Furthermore, multimedia facilitates the communication between potential users (product designers and customers) more easily in this digital era.

2.2.2 Insight into User Needs

One of the most important theories of human needs was developed by Maslow (1970). In the hierarchy of need theory, the first level of needs includes the living requirements such as food and water. After this fundamental need is satisfied, the next need is for safety and stability. The third level is concerned with love, affection and belonging. Humans desire for a harmonious relationship with others in society. The fourth level is about ego. According to Maslow, most people are not content with just meeting their ‘egotistic’ needs, they also need self-actualization. The theory can be applied to understand how a product or service can be perceived as satisfying different levels of consumer needs. Maslow’s theory identifies five levels of human needs according to importance, from low-level to high-level. The theory suggests that people start looking for something higher as they meet lower level needs.

Based on Maslow’s hierarchy of needs, Pooler (2003) defines customers’ motivations in five different levels. The first level is shopping for basic essentials of human existence. The second level is shopping for products necessary for health and safety such as sport equipment and firefighting equipment. The third level is shopping to satisfy social needs. The fourth level is shopping to meet the need for self esteem. Finally, the fifth level is shopping for self-realization.
From a slightly different perspective, Jordan (2000), having adapted Maslow's hierarchy of needs and applied it to human factors, proposes a model for product development to meet customers’ needs. The lower level incorporates the functionality and usability of the product. If these are satisfied, customers will move upward to satisfy the need for pleasure. However, because individual customers' behavior and personality are different, their perceptions and cognitions from the same stimulation tend to be different. A product can often satisfy all the needs of one customer; but at the same time can only address the lower level needs of another. Therefore, any product that allows customization by the customers will be more competitive in the marketplace.

2.3 The Difference between Product Benefits and Customer Value

A product serves as an interface or a mediator that provides product benefits and customer value to users. Product benefits consist of functionality, usability and pleasure in ownership and use. Customer value is the trade-off between perceived benefits and perceived cost. However, not all product benefits are perceived as needed by the customers. Therefore, only those benefits to the individual customer are valued. Figure 2.1 illustrates how product functions as an interface between supply and outcome.

2.3.1 Enhanced Product Benefit

There are different emotional states of pleasure that are evident in human interaction with products, society, and the environment. Nagamachi of Kansei Engineering in the 1970s focused on investigating the way feelings and impressions translated into product attributes. Nagamachi and other researchers sought further to quantify
human emotions derived from the customer’s feelings of desire (Horiguchi & Suetomi 1995; Nagamachi 1995). This has led to much research and testing in the field of “emotional” satisfaction, so that pleasure is seen as a major factor in product selection. Pleasure is now seen as a valuable product benefit only exceeded by performance and functionality (Green & Jordan 2002). Jordan (2000) refines an emotional model in product design with four dimensions of pleasure. They are: physical-pleasure, socio-pleasure, psycho-pleasure and ideo-pleasure. These manifest from both personal and social interactions with products. A successful product should provide maximum customer pleasure via these four dimensions.

2.3.2 Customer Value

Value Engineering originated with Lawrence D. Miles in 1947 when he applied his method to achieve lower costs for products and services at General Electric (Miles 1961; Younker 2003). Since then the value concept has had a deep impact
on product development. Weinstein and Johnson (1999, p85) define ‘the customer value as the ratio between the customer’s perceived benefits and the perceived cost used to obtain those benefits’. However, only the perceived product benefits are desirable to the customer. Each product benefit differs from customer to customer according to their preferences. On the basis of their definition, there are two ways to maximize customer value: (1) minimize the perceived cost, and (2) maximize perceived product benefits.

(1) Minimizing perceived cost
The perceived cost includes the time spent on searching for the products, the cost of obtaining the products and maintenance. Companies can also minimize the perceived cost through cost reductions in manufacturing and upkeep. Another approach is to offer customers a friendly purchase platform.

(2) Maximizing perceived product benefits
Another way to achieve greater customer value is to build directly on perceived product benefits. LaSalle and Britton (2003) propose a value model for new products that incorporates the main qualities at the physical, emotional, intellectual and spiritual levels. However, product benefits can only be perceived when the product qualities connect to personal values. Therefore, to follow this theory, companies should develop individual customer experiences to give the most pleasure through emotional, intellectual and spiritual connections.

2.4 Promoting Customer Value by Value Experience

In a highly competitive market, it is critical to revitalize well-established products by enhancing their value. Customers tend to purchase the products that offer
the highest perceived value (Kotler 1997). Traditionally, companies tended to incorporate substantial benefits, such as improved functionality and usability, into products for the mass market (Jordan 2000). As a result, they addressed primarily lower level needs. They did not address directly the upper level needs, such as those related to personal and social well-being.

In today’s highly competitive marketplace, addressing the upper-level needs by demystifying such intangible benefits can give a company a competitive edge. For example, companies can achieve this through marketing, merchandising devices, and innovations that could improve the product’s image value to the customers. It is in the interests of any company to offer enhanced customer value by providing experiences that go beyond customer expectations (Weinstein and Johnson 1999). Customers do not know what new features a company should offer until they interact with the new products or services presented. The way to promote these improved benefits is to assist customers in discovering them (Manning and Reece 2004).

The value experience has been defined as – ‘a product or service that when combined with its surrounding experience events goes beyond itself to enhance or bring value to a customer’s life’ (LaSalle & Britton 2003, p38). A product cannot exist by itself because it interacts with its surroundings. Value creation is the main objective in new product development and offers customers additional benefits such as safety, comfort, and pleasure. In the perception of value, it is necessary to establish how a product opportunity can be identified in a highly competitive era. Experiential concepts assist designers to offer greater value to products and turn them into design solutions. It is therefore important to ask what kinds of experiences are sufficiently valuable to transform products into desirable experiences.
2.5 Summary

This chapter has argued that the fulfillment of potential desires is important for new product development in what has been referred to as the ‘fantasy’ era. Enhanced customer value is achieved through going beyond customer expectations, and such value may well be intangible as demonstrated by the growth experienced in the entertainment industry.
Chapter 3 The Formulation of A Virtual Visualization Strategy

Chapter 3 discusses the formulation of a design strategy. The strategy is aimed at facilitating the fulfillment of customers' desires by way of enhancing the product value through value experience in the fantasy era. Furthermore, this chapter proposes the associated design techniques, marketing tools, essential components and design tools to fulfill Enhanced Value Experience. It also highlights the interconnectedness of these components and the importance of adopting an integrated design method in formulating a competitive design strategy.

3.1 Value Experience for Product Development

As discussed earlier, one of the premises for the competitive design strategy is to provide enhanced value for existing products. Enhanced value means offering better quality or services, that are meaningful and valuable to customers, than competitors are able to (Hulbert et al. 2003). In particular, a company producing mature products can no longer use price and functional advantages to create product differentiation. Instead, the company should transform the existing products by providing a unique quality in line with significant customer value. The value experience has been well applied in the entertainment industry and service industry for decades. However, such applications have not been extended to product development. Pine and Gilmore (1999) argue that the value experience makes a product memorable. Value experience gives companies a medium to offer products with enhanced value. Shaw (2005) also stresses that companies should stage attractive value experiences which arouse positive customer emotions.
3.1.1 Value Experience of Differentiated Product Appearance

One value experience for product development is the differentiation of product appearance. The differentiated appearance serves as a product image. The visual satisfaction makes a product more valuable than others. Postrel (2003) states that aesthetic identity signals both personal expression and social communication. Beardsley (1983) states that aesthetic experience directs the customer’s attention to products that are attractive and they disregard the other products. Product image is important with soft functionality such as pleasure, so that customers are willing to pay a higher price. Through evaluating different product appearances, customers can discover their ideal products. In the end, customers would search for the most valuable product that yields visual satisfaction, personal image, and novelty. In response, companies can offer alternative product appearances to these customers. However, product variety leads to a higher cost of production. In addition, the interaction between the product, its customers and the surrounding events determines the product's success in a competitive market. In short, it is important for a company to provide flexibility in an efficient manner. This is exactly the issue addressed by this research: proposing a creative design technique.

3.1.2 Value Experience of Customer Involvement

Customers are not always satisfied with the products available in the market. A gap exists that can be bridged with better customer interaction. To bridge the gap, Bjerke and Hultman (2002) propose that companies can show the prototypes to customers, collect feedback, and evaluate the alternatives, to further engage in the design process. However, showing the prototypes during the design formation lacks efficiency due to the difference of individual customers. Therefore, Prahalad and Ramaswamy (2004) stress the importance of the co-creation value between
consumers and companies and creating an efficient experience environment. The value of customer involvement is of great significance at the design formation stage. Through good interactions, customers send essential information to the company that offers the optimal product to individuals. Through the value experience of customer involvement, customers' unique desires can be achieved. Based on the value opportunity, companies should offer a communication platform to assist customers in fulfilling the purpose.

3.1.3 Value Experience of the Surrounding Environment

A product cannot exist by itself; it interacts with its surrounding environment and users. With the inclusion of the factor of the surrounding environment, the value experience is complete. In contrast to the active interaction between product and user, the relationship between the product and the surrounding environment tends to be passive and often neglected. The value of the surrounding environment lies in the interaction with products where the customers purchase, use, and own them. Before the purchase, companies establish the bricks-and-mortar or the communication platforms in which customers search for the ideal products, with the shop image parallel to be friendly interface. Kooijman (2004) states that the shop environment plays an important role in the interaction and relationship with customers. Therefore, the surrounding environments incorporate the entire place where products have been involved. The most typical surrounding environment is the interior, such as the furniture and home appliances. In addition, the atmosphere of the shop environment and the virtual platform (where the products are displayed) significantly affect purchase decisions.
3.1.4 Value Experience of Variety Seeking

The experience of variety seeking is an important process for customers which provides opportunities for browsing related possibilities. Customers, then, search for the optimal options before they make the purchase decision. Variety seeking serves as the function of assisting customers to deal with the changing environments (Kahn 1998). Even customers who do not make a purchase will still appreciate a physical and emotional experience. Thus, the company should offer effective portals where customers can discover the desirable products easily. The value experience of variety seeking gives incentives to designers in offering various products that satisfy customers with pleasure and unique experience by the distinguished product appearance. Furthermore, it provides the possibility of searching for the optimal products within potential environments.

3.1.5 Enhanced Value Experience

The four main value areas of Enhanced Value Experience are: (1) differentiated product appearance, (2) customer involvement, (3) surrounding environment, and (4) variety seeking. These are based on the definition of value experience, ‘a product or service combined with its surrounding experience events could enhance value to customer’ (LaSalle and Britton 2003, p38). In addition, on the basis of strategic marketing principles, well-integrated value experience could offer differentiated and perceived value (Shaw 2005). Therefore, the Enhanced Value Experience could incorporate the four sub-sets of value experience, where variety seeking plays the connection role in the process of enhanced value creation. Through the variety seeking process, the customer can easily experience the full spectrum of differentiated product appearance with the environment interaction. It provides a value opportunity that facilitates customers in discovering potential...
needs through the pleasure experience of product appearance with its surrounding events. Normally, each value experience can be easily realized. The integration of the *Enhanced Value Experience* has made the problem complicated. However, the added challenge now is to demonstrate the importance of successful integration for fulfilling the value opportunity. Figure 3.1 illustrates *Enhanced Value Experience* derived from the integration of four types of value experience.

![Figure 3.1 Enhanced Value Experience](image-url)
3.2 Formulation of A Virtual Visualization Strategy

Traditional product development and existing market strategy can no longer accommodate the diverse customers of a mature market. As discussed earlier, a company in the maturity stage should develop differentiated strategies in promoting enhanced value of products and distinguishing the company's offerings from the competitor's to the customers. *Enhanced Value Experience* has been identified from the experiential perspective with the following four types of experiences: (1) differentiated product appearance, (2) customer involvement, (3) surrounding environment, and (4) variety seeking.

The experience of differentiated product appearance is related to product development, while variety seeking and customer involvement are related to customer behaviors. The experience of the surrounding environment is related to the place where the products interact. The four types can be easily achieved separately by offering alternative pre-made products, exhibition centers, and marketing research. This is the current practice in product development. However, the four types also affect each other. By connecting them, they bridge the gaps between product, environment, and users that have been neglected in current product development. The challenge is to search for the best solution for staging the four types simultaneously; hence creating the *Enhanced Value Experience*.

A notion is provided by the *Virtual Visualization Strategy*. This integrates mass customization as the marketing strategy with interactive 3D as the intuitive communication platform. Figure 3.2 illustrates the architecture of the *Virtual Visualization Strategy*, consisting of design techniques, marketing tools and *Enhanced Value Experience*. 
3.3 Marketing Tools of the Virtual Visualization Strategy

The *Virtual Visualization Strategy* offers marketing tools consisting of interactive 3D and mass customization. These marketing tools serve as the communication platform between customers and companies.

3.3.1 Interactive 3D

Company product marketing today consists mainly of text descriptions, pictures, and static models to communicate the product. Although these formats can generate relevant product information, they lack the capability of user interaction with the product. The *Virtual Visualization Strategy* requires a communication platform that can intuitively simulate the design process. The technology of interactive 3D
has been successfully applied in many fields such as aviation training, military simulation, and 3D game design. It demonstrates that well-integrated interactive 3D in the product development process reduces cost and improves efficiency. In addition, interactive 3D bridges the gap between simulation and reality through strong visualization and interaction capabilities. Therefore, interactive 3D needs to play a key role in product development. The integration of mass customization systems and interactive 3D with its high flexibility can provide a new vision for product development.

3.3.2 Mass Customization

An intelligent way for discovering potential products is to engage customers with the simulation of design processes. Mass customization allows customers to go through similar mental experiences as the product designers during the purchase process. In spite of the functional factors, designers adopt product modules to generate various appearances systematically. Each product module stands for an independent fraction with perceived value to customers. Countless possibilities can be propagated through the various compositions of product modules. The various possibilities are perceived and evaluated before they are produced. Finally, only a few of the conceptual possibilities emerge in the market for the target audiences. Therefore, mass customization serves as a basic marketing tool by which a similar design process can be engaged.
3.4 Design Techniques for Virtual Visualization Strategy

There is a range of design techniques but three techniques are particularly appropriate for the Virtual Visualization Strategy. The three are: intuitive 3D transformation, compatible form design, and virtual development plane and the relevance of each will be described in turn.

3.4.1 Intuitive 3D Transformation

*Intuitive 3D transformation* provides the core technique in the Virtual Visualization Strategy. With this technique, potential products can be constructed from 3D modules. Also, *intuitive 3D transformation* bridges the gap between designers and customers, whereby the customer can participate in the design process. This should give a sense of self-achievement and enhance the value experience. This new technique combines 3D modules and 3D transformations, leading to unlimited product possibilities. With it, virtual products can be constructed digitally. The implementation of intuitive 3D transformation assists customers in searching for desirable products and in discovering product potential in a virtual environment. In combination, they provide a platform where customers can explore, instead of accepting, a predefined product.

3.4.2 Compatible Form Design

To support these product possibilities, the 3D database of product modules should be constructed with a formation grammar that ensures that (a) the entire parts inventory is meaningful, and (b) it does not allow impossible combinations. This formation grammar is the foundation of the 3D database of product modules and it incorporates different product parts with functional intentions. In the Virtual
Visualization Strategy, the aesthetic experience drives the compositions of various 3D product modules rather than predefined alternatives. Therefore, all components should be compatible with each other. There are two ways for engendering compatible forms:

(1) Interactive behavior
Interactive behavior exploits the logical components within the interactive 3D environment to create compatible combinations. With this method, the database of 3D product modules can provide a wider range of possibilities. Designers can generate various styles of 3D modules to propagate broadly based possibilities. Designers need to deal with complicated interactive possibilities for each 3D product module. However, this interactive behavior encourages the propagation of more differentiated products.

(2) Pre-sifting
Another way of creating compatible 3D modules is to build them with a pre-sifting method. This method employs the preselected 3D component modules to develop a meaningful 3D database which ensures high compatibility. Designers should generate and determine all the 3D product modules before they are exported to a product database. The application in this research adopts this method.

3.4.3 Virtual Development Plane

Most traditional companies exploit a product platform to offer various products for target audiences. In a homogenous market, this is differentiated by a share of the physical segment of their components (Ulrich & Eppinger 2004; Meyer & Lehnerd 1997). Only limited predefined products can be produced by this product platform for this segmented market. Furthermore, the personal products with more valuable
acceptable features are harder to realize. To overcome this, an advanced product interface is needed for generating highly differentiated products. First, a virtual development plane is constructed as the advanced product interface: it represents the product’s position and orientation in the virtual space. To propagate all design possibilities efficiently, the virtual development plane integrates with the virtual plane and the interactive 3D. It serves as the visual reference plane rather than the substantial plane, as only the elicited products will be produced. All of the various combinations can be virtually created on the virtual development plane. In addition, the distinction between each product is unconstrained.

3.5 Essential Components of the Virtual Visualization Strategy

To achieve the Virtual Visualization Strategy, the essential components should be established before integration. Each component serves an essential function and the components interact with each other through interactive 3D. In this way customers can experience the enhanced value in their choice through the internet. Although it is compatible to other representation equipment, such as immersion virtual reality, cave virtual reality, and 3D projection virtual reality. Its main use in this project is to develop a virtual visualization platform on the internet. Customers, then, can access the virtual space from a variety of portals on the internet. The components of the Virtual Visualization Strategy include: (1) 3D databases of product modules (2) 3D environment modules (3) audio and video modules (4) interface modules and (5) Interactive behavior modules. Figure 3.3 demonstrates
how the essential components of the Virtual Visualization Strategy fit together.

3.5.1 3D Database of Product Modules

The 3D database of product modules consists of all virtual product modules that incorporate functionalities and physical elements. They are the fundamental visual components of the Virtual Visualization Strategy. A large number of products can be developed through the use of product modules. These compatible product modules are the key element in differentiation. To build the 3D module database in a meaningful way, each equivalent function module must be distinguished from the other modules. Furthermore, they must be entirely compatible in an easy to use format.
3.5.2 3D Environment Modules

The 3D environment modules provide environmental settings for potential customers. The products that customers construct can then be viewed within their chosen settings. The 3D environment modules provide possibilities for interaction between products and the environment in which they are used. In so doing they assist customers to make informed decisions before they purchase. They also allow customers to decide whether a product will fit into an environment. Ideally, a 3D environment module will offer customers one that is similar to the real physical environment. However, different customers will have their own environments. Acknowledging this, the environment modules should provide a range of ‘typical’ settings that customers can identify with.

3.5.3 Interface Modules

The interface modules are designed to assist customers in experiencing enhanced value creation in the virtual environment. A friendly interface design offers users guidance to move through the virtual environment. Most of the available interface designs are composed of 2 dimensional graphic designs. In the virtual environment presented here more flexibility and diversity is brought to the interface design. It includes 3D props, audio guidance, and animation.

3.5.4 Audio and Video Modules

The audio and video modules serve as supplementary features to extend the virtual experience via, for example, oral explanations, feedback sounds, and movie demonstrations. They assist by bridging the gap between the virtual and the real.
3.5.5 Interactive Behavior Modules

Interactive behavior modules are central to interactive 3D. The interactive behavior for a behavioral object is composed of many building blocks with detailed parameter settings. To achieve this, programmers can use the Virtools Scripting Language within Virtools Dev for advanced application development. Normally, the building blocks, with their countless possibilities of composition, are enough for general applications. The performance of interactive behavior is extremely important for a friendly interface, maintaining a connection between users and the virtual visualization platform. The flexibility of interactive 3D makes it possible to explore the potential of breakthrough path and innovations. In short, interaction and integration is possible with well designed interactive behavior modules.

3.6 Design Tools of the Virtual Visualization Strategy

The design tools used in this design research can be categorized in terms of their utilities. They include 2D graphic, 3D modeling and interactive 3D tools. Choosing the appropriate design tools is to evaluate the interactive 3D with the criteria of flexibility and compatibility and adopt it as the integrated media program through the whole design process. The program flexibility concern is whether the integrated media offers an extensive application that caters for the necessity of the Virtual Visualization Strategy. Moreover, the compatibility ensures that the interactive 3D program can integrate associated tools effectively. Once the integrated media has been identified, this is followed by assessing the related design tools. In conclusion, flexibility and compatibility facilitate and streamline data sharing and interaction in achieving the Virtual Visualization Strategy successfully. Figure 3.4 illustrates the design tools that have been used, ranging from 1 dimensional to interactive 3D.
3.7 Summary

This chapter has described the formulation of a Virtual Visualization Strategy for the creation of personalized products. To achieve this, each product can be made of components integrated in different functional virtual layers, and located within a series of virtual environments.
Chapter 4 An Application of the Virtual Visualization Strategy

Chapters 4 and 5 describe an application example of the Virtual Visualization Strategy in the product development field of Chinese-style furniture. The application of the Virtual Visualization Strategy demonstrates how designers can exploit the proposed design strategy to enhance value by offering an experiential virtual platform. This chapter starts with the building of the 3D database of product modules. The 3D database is a revolutionary way of enabling customers to surf the interactive design platform.

4.1 Architecture of the 3D Database of Furniture Modules

The building of a 3D module database is applied in two furniture families. One product family includes Zen chairs, tea chairs and living room chairs. They share common product modules and can be adapted to provide different functionalities. The other family contains individual sets of desks and reading chairs. These two families provide varieties across different functional furniture items by making changes on the virtual development plane, an orientation where the 3D product modules can be composed according to the chosen product architecture. Meyer and Lehnerd (1997) argue that excessive product variety results in complexity. Adopting modular construction can greatly simplify the task. With a choreographed virtual 3D transformation technique, virtual development plane, and compatible design only certain products will be visualized and produced. Figure 4.1 illustrates the architecture of furniture modules. It shows the relationship between different functional furniture products.
A Virtual Visualization Strategy for the Creation of Personalized Products

4.2 Design of the 3D Modular Database for the Desk and Reading Chair

Pine and Gilmore (1999) argue that companies should not rely on customers in generating new ideas, because customers cannot clearly express what they want. However, the 3D database of furniture modules can serve as a virtual incubator to assist customers. Modular architecture facilitates varieties by adopting changeable combinations of components in forming various products (Ulrich et al. 1998). Therefore, an ideal way to form the architecture of the reading desk and chair is by harnessing modular construction. The reading desk can be built with the top and base modules, based on functional and physical differentiations. Correspondingly, the reading chair can be built with the modules of back rest, seat, armrest, and cushion.

Before the 3D database of furniture modules can be built, the first prototype should be created. To successfully achieve the differentiated appearance and variety-
seeking experience for virtual customers, a bank of complementary product modules will be set up. The modular design of the Chinese-style furniture based on functionality makes the modules compatible and differentiated. Figures 4.4 and 4.5 demonstrate the reading chair and desk prototypes, from which modular compatibility and differentiation can be developed. The abstract concept has been explicitly visualized as a physical composition. The first prototype serves as a critical basis from which other prototypes can be developed. Figure 4.8 shows the desk and reading chair prototypes as a set.
A Virtual Visualization Strategy for the Creation of Personalized Products

Figure 4.5 Desk prototype and its virtual development plane

Figure 4.6 Desk front elevation

Figure 4.7 Desk side elevation
The development of compatible prototypes follows the digital construction of the first prototype. *Compatibility* and *differentiation* must cover the entire range of furniture modules. Figures 4.12 - 4.17 illustrate the various compatible prototypes of the desk and reading chair. When all the product modules have been developed, the construction of a 3D modular database will follow, so that potential products can be created. The most important principle to accomplish the 3D modular database is to maintain consistency through all 3D digital modules, including the 3D digital format, the orientation of 3D modules and texture mapping.

The common 3D digital format serves as the communication channel across different software platforms. The digital 3D product modules can be built by 3D...
Max, MAYA, Lightwave or compatible CAD software, while the entire 3D digital modules should be exported in the “3ds” or “Nmo” file format for suitable integration in interactive 3D.

Another area where consistency is necessary is the orientation of the 3D module, which specifies the pivot and reference points for positioning individual modules. Each furniture module should adopt the same pivot system to maintain coordinated directions with other 3D product modules. Furthermore, material mapping is related to how a product module is wrapped in changeable textures. Once the above have been achieved, all 3D product modules can be exported sequentially to build a coordinated 3D database of furniture modules.
A Virtual Visualization Strategy for the Creation of Personalized Products

Figure 4.12 Desk (Prototype 2)

Figure 4.13 Desk with reading chair (Prototype 2)
A Virtual Visualization Strategy for the Creation of Personalized Products

Figure 4.14 Desk (Prototype 3)

Figure 4.15 Desk with reading chair (Prototype 3)
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Figure 4.16 Desk (Prototype 4)

Figure 4.17 Desk with reading chair (Prototype 4)
4.3 Design of the 3D Modular Database for the Zen Chair

Another furniture family adopting the virtual development plane includes Zen chairs, tea chairs and living room chairs. This section illustrates the design of the 3D modular database for the Zen chairs. The illustrations of the tea chairs and living room chairs follow.

The traditional Zen chair, mainly used for meditation and on which users cross their legs, is popular in the Chinese community. Based on its functional benefits, the Zen chair can be built with these three modules: back, armrest and seat. In addition, the virtual development plane assists in developing the entire 3D database of the Zen chair modules. The Zen chair prototype design adopts straight lines, an S-curve and an explicit structure. Figures 4.18 - 4.20 display the prototype of the Zen chair with inward armrests. Figure 4.22 shows a set of Zen chairs with a tea desk that can be extended. Once the first prototype of the Zen chair has been created, compatible variants can be developed. Figures 4.23- 4.28 illustrate other prototypes of the Zen chair. When all prototypes of the 3D modules have been developed, they will be exported in the same file format, orientation and texture mapping, to ensure that each product module can interact and communicate successfully within the interactive 3D platform.
A Virtual Visualization Strategy for the Creation of Personalized Products

Figure 4.18 Zen chair side elevation  
Figure 4.19 Zen chair front elevation

Figure 4.20 Zen chair prototype
A Virtual Visualization Strategy for the Creation of Personalized Products

Figure 4.21 Zen chair prototype and its virtual development plane

Figure 4.22 Set of Zen chairs with tea table prototype
A Virtual Visualization Strategy for the Creation of Personalized Products

Figure 4.23 Zen chair (Prototype 2)

Figure 4.24 Zen chair top elevation (Prototype 2)

Figure 4.25 Zen chair front elevation (Prototype 2)
A Virtual Visualization Strategy for the Creation of Personalized Products

Figure 4.26 Zen chair top elevation (Prototype 3)

Figure 4.27 Zen chair front elevation (Prototype 3)

Figure 4.28 Zen chair (Prototype 3)
4.4 Design of the 3D Modular Database for the Tea Chair

A conventional tea chair set includes two tea chairs and one tea table that can be placed alone or with other furniture. The tea chair can be built with the seat, back and armrest modules. Using the virtual development plane, compatible tea chairs can be produced.

The prototype design of the tea chair takes advantage of both the virtual development plane and the Zen chair module parts to create an extended prototype. With these methods the tea chair can easily be developed into a series of product families. Figure 4.31 shows the tea chair prototype and some modules of the Zen chair. Figure 4.32 displays a set of tea chairs with a tea table. Following the first tea chair prototype, derivatives can be produced. Figures 4.33 - 4.38 illustrate the other tea chair prototypes. When all the visual prototypes of the 3D module are created, they will be exported in a file format that is consistent with other prototypes.
A Virtual Visualization Strategy for the Creation of Personalized Products

Figure 4.29 Tea chair top elevation

Figure 4.30 Tea chair front elevation

Figure 4.31 Tea chair prototype
A Virtual Visualization Strategy for the Creation of Personalized Products

Figure 4.32 Set of tea chairs with tea table prototype
Figure 4.33 Tea chair front elevation (Prototype 2)

Figure 4.34 Tea chair side elevation (Prototype 2)

Figure 4.35 Tea chair (Prototype 2)

A Virtual Visualization Strategy for the Creation of Personalized Products

An Application of the Virtual Visualization Strategy
4.5 Design of the 3D Modular Database for the Living Room Chair

A set of living room chairs usually includes seven chairs: two single chairs, a two-seater, a three-seater, a tea table, and a side tea table. The living room chairs are an extension of the Zen and tea chairs. As the living room chair stems from the Zen chair and tea chair, it shares the same product architecture. The prototype for the living room chair adopts the virtual development plane and modules to develop further prototypes. Figure 4.39 illustrates the living room chair prototype which includes a single tea chair, a two-seater, a three-seater, and tea tables.

Figures 4.40-4.41 show the other compatible prototypes for the living room chair. When all prototypes of the 3D modules are created, they will be exported in the same file format, orientation and texture mapping to ensure that the designs can be extracted successfully.
Figure 4.39 Set of living room chairs prototype

Figure 4.40 Set of living room chairs (Prototype 2)
4.6 Summary

This chapter has presented the practical design applications of the *Virtual Visual Strategy*. A 3D database of furniture modules has been constructed using a *virtual development plane* and *compatible design*. Two furniture families have been developed, including their 3D database of furniture modules and components. The adoption of common furniture modules produces the maximum variety of designs. Six furniture design patents have been approved by the Intellectual Property Office of the Ministry of Economic Affairs, Taiwan to protect the intellectual property of the prototypes.
Chapter 5 The Integration of Virtual Visualization Components

Various digital components such as the environment modules, interactive behavior modules and interface modules exist, which allow the user to organize the considerable number of design elements. They need to be integrated in the virtual visualization application. The design of the virtual environment will be described in section 5.1 and a referential character will be presented in section 5.2. The design of the interactive behavior module will be described in section 5.3. The integration of all virtual visualization components will be illustrated in section 5.4. Possibilities for the creation of personalized products will be presented in section 5.5.

5.1 Design of the 3D Environment Modules

Based on the premise that the product cannot exist by itself, and that it interacts with its surroundings, the environment provides one of the most important information sources for customers in making purchase decisions. The most relevant environment for the furniture is the interior in which it will be located. Presenting a simulated interior for each customer, however, is impractical. The objective, therefore, is to provide a series of representative interior settings from which the customer can choose to locate the furniture of their choice. Color is one of the most important elements of interior design (Pile 2003). Consequently, the interior design should provide customizable color schemes.

A prototype interior is required that will serve as the representative space for all interior modules. Although Chinese style will fit into non-Chinese style interiors, it
is logical to focus upon Chinese style interiors, given the assumed target market of Chinese customers. Also, given the types of furniture to be displayed, the interior should include a Zen room, living room and reading room. Figure 5.2 illustrates the layout of a Chinese style house with furniture.

There are hundreds of elements which can be created systematically by designers to build a complete house. It is complicated and needs to be simplified. The methods are: ‘name’, ‘attach’ and ‘layer’ (Baek 2002) within 3D modeling software. The first step of the systematic construction method is to create a recognized ‘name’ that can truly reflect an element’s characteristic. The method of ‘attachment’ allows designers to combine similar elements so that it simplifies the composition of a house. The method of ‘layering’ assists designers to classify entire elements according to their functions in the virtual space to manage and design using 3D software. Figure 5.3 demonstrates the virtual Chinese house created by the systematic construction method.
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Figure 5.1 Virtual Chinese house front elevation

Figure 5.2 Virtual Chinese house layout

Figure 5.3 Virtual Chinese house prototype
5.2 Referential Character Design

The experience of scale in virtual space is extremely important. A character has been constructed to act as a reference point for both furniture and interior. In the past, designers created characters by 3D modeling software such as 3D Max, MAYA, and Lightwave, through a complicated and time consuming process. The Poser software has been adopted, by which designers can create characters efficiently.

Once the character has been built, it will be exported to 3D modeling software for detailed design, such as mesh optimization, texture mapping, biped and animation. The mesh optimization simplifies the character mesh to minimize file size for running more smoothly in the virtual space. The biped serves as the bone system of the character by which the animation can be constructed. It requires two kinds of animation: one in the waiting status and the other walking. The waiting animation can be done by setting the keyframe with the transformation method. The walking animation can be created through combining the specified multi-footstep. Figure 5.4 shows a character with its biped and walking animation and Figure 5.5 illustrates a waiting animation design with key frames.
5.3 Designing the Interactive Behavior Modules

Interactive behavior modules are the internal processing mechanisms. They make the virtual experience possible through their integrated performance and flexible compatibility. Their functions are to integrate and interact with the other components. Therefore, interactive behavior modules can be attached to the 3D database of product modules, 3D environment modules, audio/video modules and interface modules. This entire application needs hundreds of interactive behaviors for each digital module. Part of the representative behaviors will be demonstrated below.
5.3.1 Interactive Viewpoint

The viewpoint is named as a ‘camera’ within Virtools Dev. It represents a viewpoint of users (Virtools 2004). Through the viewpoint customers can easily explore the virtual space. The interactive viewpoint includes the ‘building blocks’ (Carthy & Callele 2001) of: (1) camera control and (2) object slider. The camera control offers users the functions of rotation and translation through the arrow keys that simulates users’ perspective. The setting of the object slider impedes the camera viewpoint from penetrating a 3D object in the obstacle group. Figure 5.6 displays the interactive viewpoint scheme, composed of building blocks of switch on key, per second, rotate, and translate.

![Interactive Viewpoint Diagram](image-url)
5.3.2 Interactive Behavior of Intuitive 3D Transformation

The interactive behavior of *intuitive 3D transformation* is the core of the *Virtual Visualization Strategy*. It enables customers to create various virtual products intuitively. A creative design notion will be adopted to achieve this purpose. First, each furniture module serves as one of the ‘behavioral objects’ (Carthy & Callele 2001), consisting of position, orientation, scale, object mesh, material, and texture. The 3D object and object mesh are the elements of the form for each virtual digital module in Virtools Dev. A 3D object is displayed using a mesh. A mesh is the physical structure of a 3D object. It describes the geometrical representation of the object. In addition, a 3D object can use different object meshes in Virtools Dev (Virtools 2004). The 3D object records the data of material mapping, position, and orientation, while the object mesh records the geometrical data. Therefore, the object mesh is the key element of intuitive 3D transformation. An interactive behavior of *intuitive 3D transformation* can be developed, based on the interchange of product module meshes.

Figure 5.7 illustrates part of the interactive behavior of intuitive 3D transformation. This incorporates the building blocks of *wait message, broadcast message, remove mesh*, and *select mesh*, whereby the 3D furniture modules can be transformed, as they receive messages from the users’ interactions. The *wait message* is activated when the awaited message from the user is received. The *broadcast message* sends a message to the 3D objects which share the same object mesh. *Remove mesh* means withdrawing an existing mesh from the selected 3D module. *Select mesh* specifies which mesh should be used to represent the geometrical visualization of a 3D furniture module.
Another critical element is the material. A material contains the surface description for the faces of a mesh. A material most often uses a texture (Virtools 2004). However, the texture affects the visualization significantly by the use of colors and grains. Figure 5.8 shows one of the interactive behaviors of an interior floor material which is composed of the building blocks of planar reflection, wait message and set texture. The planar reflection is only used for glossy material such as marble and glass. It assists in simulating the real material. The texture of a 3D object will be reset when it receives an activated message by direct clicks on it. Other simulated materials for the interior and furniture will be attached to the interactive behavior of material interchange, which includes the walls, cushions, chairs and desks.
5.3.4 Interactive Behavior of Character Animations

The character serves as the reference point when users access the virtual space. The interactive behavior of the character has been designed in terms of the placement of the furniture. According to the furniture’s placement, the interior layout is in four grids, that are: the tea room, Zen room, living room, and reading room. Once the furniture has been selected, it sends a message to the referential character, and the character will walk along the grid path. Finally, the character stands beside the activated furniture and faces the camera. Figure 5.9 illustrates the behavior of the character. It is mainly composed of building blocks of the unlimited controller, wait message, grid path solver, character curve follow, set orientation and timer.
5.3.5 Behavior Modules for Rotation and Movement

The virtual space offers customers an intuitive 3D visualization of the furniture, whereby they inspect it from different angles and viewpoints. The functions involved are shown in Figure 5.10.
5.4 Integration of Virtual Visualization Components

When all virtual visualization modules have been constructed they will be integrated into a common virtual platform where customers can create their own furniture via the internet. Based on the interactive behavior modules which have been developed previously, the interactive behavior modules of intuitive 3D transformation, material interchange, and rotation can be implemented on each furniture and interior module. Once the interactive behaviors of furniture modules have been set, they can be merged with their interior modules, which include the reading room, Zen room, tea room, and living room. When all the virtual components have been integrated into the common platform, they will be exported as a virtools player format and subsequently published on the internet.

Figure 5.11 illustrates the digital modules of desk, and reading chair with reading room. Figure 5.12 illustrates the integrated reading room that has been exported as a web page. Figure 5.13 displays the digital modules of Zen chairs with Zen room. Figure 5.14 illustrates the integrated Zen room that has been exported as a web page. Figure 5.15 displays the digital modules of the tea chairs with tea room. Figure 5.16 illustrates the integrated tea room that has been exported as a web page. Figure 5.17 displays the digital modules of the living room chairs with living room. Figure 5.18 illustrates the integrated living room that has been exported as a web page. Figures 5.19 - 5.20 illustrate the integration of the interface and instructions to guide the customers in creating personalized furniture within its interior.
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Figure 5.11 Digital modules of desk and reading chair with the reading room

Figure 5.12 Exporting integrated reading room as a web page
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Figure 5.13 Digital modules of Zen chair and Zen room

Figure 5.14 Exporting integrated Zen room as a web page
Figure 5.15 Digital modules of tea chair and tea room

Figure 5.16 Exporting integrated tea room as a web page
Figure 5.17 Digital modules of living room chairs with living room

Figure 5.18 Exporting integrated living room as a web page
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Figure 5.19 Interface and instruction for virtual creation platform

Figure 5.20 Interface guides customers to furniture creation with its interior
5.5 Possibilities for the Creation of Personalized Products

When all the digital components have been integrated and exported as web pages, the creation of personalized products is possible. A total of 1280 (4^4 * 2^2 * 4^5) possibilities for a set of desk and reading chair can be achieved. A total of 270 (3^3 * 2^2 * 3^5) possibilities for a set of Zen chairs can be achieved. A total of 540 (3^3 * 3^4 * 5) possibilities of a set of living room chairs can be achieved. A total of 180 (3^3 * 4^5) different possibilities of the tea chair can be achieved.

Figure 5.21 illustrates some variations of the desk. Figure 5.22 illustrates some variations of the desk with reading chair. Figure 5.23 illustrates some variations of the Zen chair. Figure 5.24 illustrates some of the variations of tea chairs. Figures 5.25 - 5.26 illustrate some of the variations of living room chairs. Figures 5.27 - 5.36 illustrate some variations of furniture with customizable interiors for customers to create their own personalized products.
Figure 5.21 Variations of desk
Figure 5.22 Variations of desk with reading chair
Figure 5.23 Variations of Zen chair
Figure 5.24 Variations of tea chair
Figure 5.25 Variations of living room chairs
Figure 5.26 Variations of living room chairs
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Figure 5.27 Variations of desk with reading chair and reading room

Figure 5.28 Variations of desk with reading chair and reading room
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Figure 5.29 Variations of desk with reading chair and reading room

Figure 5.30 Variations of Zen chairs and Zen room
Figure 5.31 Variations of Zen chairs and Zen room

Figure 5.32 Variations of Zen chairs and Zen room
Figure 5.33 Variations of tea chairs and tea room

Figure 5.34 Variations of tea chairs and tea room
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Figure 5.35 Variations of living room chairs and living room

Figure 5.36 Variations of living room chairs and living room
5.6 Summary

This chapter has described how the interactive components have been systematically integrated into a virtual platform. Representative examples of furniture have been depicted. Finally, potential furniture design selections have been created for customers’ choice.
Chapter 6 Conclusion

This design research project makes a number of contributions to the promotion of mature products in an intensely competitive market. The contributions can be summarized as: (1) the identification of a value opportunity, (2) the formulation of the Virtual Visualization Strategy, (3) the creation of an integrated product development incorporating multimedia, (4) the invention of a virtual intuitive 3D transformation and a virtual development plane, and (5) the development of an intuitive virtual platform for creating personalized products.

(1) Identification of a Value Opportunity

To revitalize mature products in a competitive marketplace, an Enhanced Value Experience has been identified for promoting higher product value. This shifts product development from product benefit to experiential value.

(2) Formulation of the Virtual Visualization Strategy

To achieve the Enhanced Value Experience, the Virtual Visualization Strategy has been formulated. It incorporates four functional layers: key technique layer, integration and communication layer, experience layer, and decision making layer. The Virtual Visualization Strategy can assist designers to create unique product positioning.
(3) Creation of an Integrated Product Development Incorporating Multimedia

State-of-the-art technology – in particular, interactive 3D – has been employed to enhance product value.

(4) Invention of A *Virtual Intuitive 3D Transformation* and A *Virtual Development Plane*

The *intuitive 3D transformation* enables customers to explore variations with dynamic 3D prototypes in intuitive 3D visualization. The *virtual development plane* enables a range of visual possibilities to be offered. The combination of both techniques provide a more efficient method in searching for the best fit in product module selections for both customers and product designers.


The application of furniture development has demonstrated that an intuitive virtual platform for creating personalized product can be achieved via the internet. It provides product and environment differentiations for individual customers to choose from.

This design project proposes a *Virtual Visualization Strategy* to enhance value for a mature product such as furniture. The outcome of the project has yielded six design patents. Although the *Virtual Visualization Strategy* mainly caters for mature ‘aesthetic-oriented’ products, the project does suggest that it could find application beyond this particular type of product; for example, new products entering a market.
Finally, the intention of the research project was to investigate the concept of a *Virtual Visualization Strategy* and to construct a prototype. While both have been achieved, they none-the-less represent the initial stages of a fully operational system. Clearly, further development work is now needed to bring the concept to a marketable proposition. It is intended that this will be undertaken as a cooperative venture in an industry-university business partnership in Taiwan.
Appendix

This design research has resulted in the production of a 3D modular database that shows potential design possibilities. The virtual demonstration of the application of the Virtual Visualization Strategy, and other support information is included on a DVD.

The attached DVD contains electronic copies of the following material:

(1) An application of the Virtual Visualization Strategy.
(2) A copy of the thesis in PDF format.
(3) Six approval letters concerning design patents from the Intellectual Property Office of the Ministry of Economic Affairs, Taiwan.

The application of the Virtual Visualization Strategy requires the Virtools player to display and interact with it. The Virtools player is available free from http://www.virtuools.com/downloads/playerie3.5.asp. Furthermore, the documents in PDF format require Adobe Acrobat Reader to view the files. This is available from http://www.adobe.com/products/acrobat/readstep2.html


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