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A Conflict between Professional vs. Domestic Life? Understanding the Use of ICT in Teleworking for Balance in Work and Family Units

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Abstract

The advancement of information and communication technologies such as personal computers, the Internet and mobile phones has enabled people to work any time and anywhere. Teleworking, the practice of setting up home offices for employees with appropriate resources for computing and communication, is one example of this new flexibility. Teleworking brings new challenges as well as benefits, and a variety of studies have examined the impact of teleworking in terms of costs and benefits. A major attraction for teleworkers is the control it allows them over the way they structure their work and lives. However, the intrusion of work into the home blurs the boundaries between work and home life and may result in conflict between work and family. This work-family conflict is a direct result of the mutual incompatibility between the demands of work and family roles (Akdere, 2006). The aim of this research is to study the work-family balance of Malaysian teleworkers by exploring the nature of interactions between work and family activities, in order to get a better understanding of the experience of teleworkers in balancing their work and family life. This study will use the work-family border theory (Clark, 2000) to describe the phenomenon, and to explain how individuals manage and negotiate the work and family spheres and the borders between them in order to attain balance.

Keywords: Teleworking, Work-family balance, Work-family border theory, Boundary theory

1. Introduction

It has been stated that long working hours deprive individuals of the time that they should spend with their families (Ammons & Markham, 2004).Work-family conflict also occurs when individuals have to perform multiple roles (e.g. worker, spouse, parent, and neighbor) at the same time (Carlson et al., 2000); therefore, individuals have difficulty establishing their multiple roles when working from home. The use of ICT has increased the permeability of work-family boundaries because these technologies make individuals accessible any time and anywhere; as a result the boundaries of work and family increasingly blur (Lewis & Cooper, 1999; Nippert-Eng, 1996). This can promote conditions such as overwork and isolation, which may lead to greater stress on individuals and families (Baines & Gelder, 2003; Chelsey, 2005). Conversely, individuals may spend more and more time on housework activities which may have a negative impact on their job performance (Ahrentzen, 1990; Ashforth, Kreiner, & Fugate, 2000; Golden, Veiga, & Simsek, 2006; Kossek, Lautsch, & Eaton, 2006; Olson-Buchanan & Boswell, 2006).

Distraction from family members often occurs while working at home because others assume that the teleworker is available to visit, run family errands and do household activities (eHomemakers, 2003). Children especially do not perceive a dividing line between work and play when they see their parents at home all the time (Tan-Solano & Kleiner, 2001). Each of these conflicting roles places demands on time, energy and commitment, which eventually results in work-family conflict (Edwards & Rothabard, 2000). Bringing work home can also interfere with home life if it becomes difficult to set aside work and focus on family activities (Desrochers, Hilton, & Larwood, 2005).

To find strategies to minimize the problem of blurring boundaries some researchers have focused on the structure of work in time and space (Ahrentzen, 1990; Salazar, 2001). Individuals are advised to work only at certain times to prevent home becoming a workplace, and only at certain places in the house to avoid interference from family members (Ahrentzen, 1990; Salazar, 2001). Sample strategies include having a separate room for office use only, or using a kitchen table as work desk only when no one else is home, or working with the door closed, phone off and not checking e-mail while working (Kossek, Noe, & DeMarr, 1999; Nippert-Eng, 1996). However, there is a greater potential for work-family boundaries to erode and for interruptions to take place, due to the difficulty of shifting the roles between work and family particularly when the shift is needed in an unexpected timeframe (Ashforth et al., 2000). For example, conflicting roles may arise when a person is required to engage in longer working hours to finish up an assignment, but at the same time he or she also needs to attend to the family needs. When these conflicting issues cannot be resolved, the merging of roles, space, and time can cause disruption to both work and family life (Mahmood, 2002). Therefore, finding ways in which individuals can successfully manage the boundary is essential in order to achieve work-family balance.

Researchers have identified conflicts between paid work and family roles as a major problem for teleworkers (Felstead & Jewson, 2000). Since work is done in the home, teleworkers have difficulty separating their work and family activities, which sometimes may be problematic. Conflict arises when teleworkers have to fulfill the demands of work (e.g. completing a task) and family obligations (e.g. taking care of sick children or children with disabilities) at the same time (Carlson, Kacmar, & Williams, 2000; eHomemakers, 2003). Balancing multiple roles has become a critical challenge to many working individuals (Akdere, 2006). Dowse & Underwood (2001) believed that failure to balance these roles may result in serious and undesired life events such as marriage breakdowns, social problems and ill health. Further, there is evidence that when employees experience conflict between work and family roles, they also report experiencing greater job dissatisfaction and fatigue and lower life satisfaction (Edwards & Rothabard, 2000; Frone, Russel, & Cooper, 1992).

Promoting teleworking as a solution to the work-family balance should be done carefully, as it may intensify the challenges rather then reduce them if the individual is unable to successfully balance the demands of work and family (eHomemakers, 2003). Thatcher & Zhu (2006) argue that to be a successful teleworker, individuals must have the appropriate personal qualities that allow them to manage and negotiate conflicting work and family activities in order to attain balance. The term "work-family balance" refers to individual having control over when, where and how they work, leading them to be able to enjoy an optimal quality of life as well as family (The Work Foundation, 2005).

The general aim of this research is to study the work-family balance of Malaysian teleworkers by exploring the nature of interactions between work and family activities, in order to get a better understanding of the experience of teleworkers in balancing their work and family life. Both work and family are central to our lives (Akdere, 2006); therefore, it is important for men and women to harmonize their working life and family life, especially for those who are working from home (Tan-Solano & Kleiner, 2001), and for family life practitioners to be able to offer effective strategies to teleworkers (Wiley, Branscomb, & Wang, 2007). Finding the balance can help the teleworker's well-being as well as his or her work outcomes (Standen, Lamond, & Daniels, 1999). Perhaps one of the widely adopted methods for attaining work-family balance is through managing the boundary between work and family activities (Ahrentzen, 1990; Clark, 2000; Hall & Richter, 1988; Kowalski & Swanson, 2005; Matthews, 2007).

Specifically, the purpose of this study is to investigate how teleworkers manage and negotiate the border between work and family activities in order to attain work-family balance. Hence, the research questions of this study are:

a. What are the factors that influence teleworkers in managing the border between work and family domains so as to attain balance?

b. Why do these factors influence teleworker in managing the border between work and family domains so as to attain balance?

c. How do teleworkers manage the border between work and family domains so as to attain work-family balance?

In this study, we will use a qualitative method by focusing on a single case study. With a single case study, this study is able to offer in-depth descriptions and explanations obtained from teleworkers who have had experiences in this form of flexible work structure. Furthermore, by using a case study method, it will allow us to retain the holistic and meaningful characteristics of real-life events – such as individual life cycles, organizational relations, and the maturation of

industries (Yin, 2003). A case study method is also able to offer a rich depiction of the teleworking and hence helps to understand what underlines the workers' relationship, interpretations, and behaviors when dealing with conflicts between work and family. For the source of data, we plan to collect data based on three types of techniques such as personal interviews, online open-ended questions, and discussion forums. Then, on a continuous basis, we will use the interpretive analysis technique to analyze the data. Consequently, we will end the data collection process when the categories emerge becomes saturated.

2. Managing the Boundaries between Work and Family in Organizations

2.1 What is Telework?

Ellison (1999) stated that the definitions of teleworking are many and varied. They are dynamic, as they reflect the changes that take place in society and technology, and often encompass a number of different styles of work. For example, it includes people working at home (such as programmers), people working from home (such as salespeople), and people working at work centres (such as telecottages and satellite offices) (Ellison, 1999). Other terms commonly used in place of teleworking are telecommuting, networking, remote working, flexible working, electronic homeworking and e-work (Avellino, 2005; Baruch & Smith, 2002; Gray,Hodson, & Gordon, 1993; Wilson & Greenhill, 2004).

The term "telecommuting" was originally coined to refer to the use of ICT to replace transportation (Nilles, 1994). Gray et al. (1993) reported that some researchers use the terms telework and telecommuting interchangeably, under the assumption that "telework" is preferred by Europeans and "telecommuting" is more popular in the United States. Others distinguish between the two (Gray et al., 1993). For example, Nilles (1998) defines teleworking as "any form of substitution of information technologies (such as telecommunications and computers) for work-related travel; moving the work to the workers instead of moving the workers to work". He defines telecommuting more specifically as periodic work out of the principal office, one or more days per week either at home, at a client's site, or in a telework center. He also asserts that telecommuting is a form of teleworking whereby all telecommuters are teleworkers but not all teleworkers are telecommuters (JALA International Inc, 1997).

Telecommuting according to Mokhtarian & Solomon (1994) is defined as using technology to work at home or at another location during regular working hours, instead of commuting to the workplace. It may be part-time or full-time, and need not exclusively involve computers. Mann et al. (2000) suggest that telework covers a whole range of different working patterns, including full time at home working for one company, part time at home working for one or several companies, full time at home but visiting the office for meetings or other occasional needs, or part or full time at remote or satellite sites. Avellino (2005) defined teleworkers as those home-workers who use personal computers (PCs) and/or the internet or mobile phone during their work. She goes further to conclude that telecommuting emphasizes reduction of work-related travel, whereas telework more broadly emphasizes the flexibility to work anywhere and any time.

In this study, telework is defined as working from home on a full-time basis using information and communications technology (ICT) tools in performing paid work (Baruch, 2000; Nilles, 1994; Vora & Mahmasani, 2002). This definition captures a wide range of activities, including workers that are home-based, outsourced, self-employed, employed directly by a company, or freelance or mobile teleworkers (Qvortrup, 1998). For purposes of this study, we will use the terms telework, teleworking and telecommuting interchangeably.

2.2 Why Telework?

The research findings regarding the effect of telework on family life issues (such as quality of work and non-work life, and balancing work and family life) have been inconsistent (Bailey & Kurland, 2002; Sinha & Monroe, 2006). For example, Rau & Hyland (2002) suggested that teleworking can reduce work-family conflict where it provides individuals with the opportunity to fulfill the demands of both work and family life. Other studies however have reported that greater conflicts arise when an individual teleworks, because of the additional demands resulting from greater family proximity and accessibility (e.g., Igbaria & Guimaraes, 1999; Kurland & Bailey, 1999). Furthermore, Hill et al. (1998) found that teleworking has no effect on work-family balance. Due to these inconsistencies, Sinha & Monroe (2006) suggest that there is a need for further investigation on balance issues among the teleworkers.

Evidence from the literature on teleworking has shown that it is not the ideal solution for work-family balance (Baruch, 2000; Duxbury, Higgins, & Mills, 1992; Hill et al., 1998; Jamal, 2007; Kurland & Bailey, 1999). Although teleworkers are satisfied with the flexibility and control of working at home, they struggle to deal with blurred boundaries between work and home life – i.e, teleworking individuals have greater difficulty in separating work and family activities (Desrochers, Hilton, & Larwood, 2005; eHomemakers, 2003; Hill et al., 1998; Igbaria & Guimaraes, 1999; Sullivan & Lewis, 2001; Tietze & Musson, 2005). Teleworking removes the physical separation between work and family roles, thus making it potentially more difficult to maintain a boundary between these roles as a result, individuals tend to work longer hours and may experience greater stress which could result work-family imbalance (Desrochers et al., 2005).

Teleworking's benefits for the community may be in the form of tangible benefits such as alleviating the number of vehicles on the road (Harpaz, 2002) and consequently reducing pollution and oil consumption (Mills et al., 2001). Other societal benefits include less noise pollution, less potential for accidents, less strain on public transportations system, and increasing the ability of organizations to hire employees with special needs (Harpaz, 2002). Rural communities also view telecommuting not only as a potential strategy for economic development but one that is environmentally friendly (Mills et. al., 2001). Table 1 summarizes the benefits and limitations of teleworking.

(Insert Table 1)

3. Applying a Theoretical Framework: Work-Family Border Theory (Clark, 2000)

This study employs the theory of work-family borders as its theoretical framework. According to Desrochers & Sargeant (2004), work-family border theory (Clark, 2000) and boundary theory (Ashforth, 2000) each contribute to the study of work-family linkages by describing the conditions under which varying degrees of work-family integration are likely to improve or diminish individual well-being. Both theories address how people construct, maintain, negotiate and cross boundaries or borders, and how people draw the lines of demarcation between work and family (Clark, 2000). Another similarity in both theories is the extent of integration or segmentation as indicated primarily by two characteristics: flexibility and permeability. When two or more domains are highly flexible and permeable with respect to one another, they are said to be integrated. Boundary theory and work-family border theory also share a similar view that, in addition to flexibility and permeability, the extent of work-family integration depends on how similar these domains are to each other (Desrochers & Sargeant, 2004).

However, the two theories differ on the nature of that relationship and its implications for work-family balance. Ashforth et al. (2000) propose that the difference or contrast between roles is part of what determines how clear or how thick the boundary is between one domain and another, which in turn influences the likelihood of work-family conflict (Desrochers et al., 2005). Matthews (2007) states that this theory tends to focus on transitions within an organizational context, although it also makes reference to transitions between organizational roles and non-organizational roles (e.g., retirement transition, transition between work roles and family roles). However, Clark (2000) believes that the clarity or strength of the work-family border is separate from the similarity of role domains, and that these two factors interact to influence work-family balance. The theory is primarily focused on the way people transition between the work and family domains (Matthews 2007)**.**

Work-family border theory is different from boundary theory in that its definition of borders encompasses not only psychological categories but also those tangible boundaries that divide time, place and people associated with work versus family (Desrochers et al., 2005). Clark (2000) in her research tries to understand the process of work-family conflict. She identifies one of the shortcomings of the earlier approaches as their lack of predictive ability, and suggests that these theories offered little guidance in either predicting work-family conflict or solving problems that arise in trying to balance work and family responsibilities.

Work-family border theory attempts to explain how individuals manage and negotiate the work and family spheres and the borders between them in order to attain balance (Clark, 2000). This theory was designed to remedy the criticism and gaps of previous theories on work and family (Akdere, 2006) by dividing the boundaries within the employees' life. The theory addresses how domain integration and segmentation, border creation and management, border-crosser behavior, and relationships between border-crossers and others at work and at home influence work-family balance. Employees in turn are seen as "border-crossers" making continuous, daily transitions between their work and family lives. For some individuals, the transition (border-crossing) may be slight, as where for example language and customs are highly similar in both domains. For others, the language and behavior expected in the work domain are very different from what is expected in the family domain, and thus a more extreme transition is required. The outcome of this theory is the concept of work-family balance, which refers to "satisfaction and good functioning at work and at home, with a minimum of role conflict" (Clark, 2000). This theory built upon role theory and has strong potential for further elucidating work and family conflict processes between the family and the workplace (Bellavia & Frone, 2005).

The central concepts of the work-family border theory are 1) the work and home domains; 2) the borders between work and home; 3) the border-crosser; and 4) the border-keepers and other important domain members. Each of these concepts will be explained in the following sub-sections. Figure 2-1 illustrates the work-family border theory of Clark (2000).

(Insert Figure 2-1)

3.1 The Work and Home Domains

Clark identifies work and home as two different domains which are associated with different rules, thought patterns and behavior. The differences between work and home can be classified in two different ways: differences in value ends and differences in value means (Rokeach, 1973 as cited in Clark, 2000). Work primarily satisfies the ends of providing an income and giving a sense of accomplishment, while home life satisfies the ends of attaining close relationships and

personal. Responsibility and capability were ranked as the most important means to achieve desired ends at work, while being loving and giving were ranked the most important means to achieve happiness at home (Clark & Farmer, 1998 as cited in Clark 2000). Because of the differences in domains, individuals often manage to integrate both work and home to some degree (Clark, 2000). Nippert-Eng (1996) explained the way people deal with differences between the two domains on a continuum, with integration at on one end and segmentation on the other.

3.2 The Borders between Work and Family

According to border theory, each of a person's roles takes place within a specific domain of life, and these domains are separated by borders, lines of demarcation that may be physical, temporal, or psychological (Clark, 2000). Physical borders define where domain-relevant behavior takes place, such as the walls of a workplace or the walls of a home (Clark, 2000). Ahrentzen (1990) discovered that much of the literature on role conflict boundaries examines controlling and setting time schedules, but rarely considers space. She found that 69% of workspaces were used exclusively for work; when a room was not exclusive, the equipment and furniture typically marked the boundaries.

A temporal border refers to a set of work hours that divide when work is done from and when family responsibilities start (Hill et al., 1998). Common examples of temporal boundaries are rituals such as kissing one's spouse good-bye, or turning on the computer and checking voice-mail messages can form the temporal boundaries that begin the day. Turning off the ringer to the office phone line or locking the door to the home office, mark the end of the day (Hill et al., 1988).

Psychological borders are rules created by individuals that dictate when thinking patterns, behavior patterns and emotions are considered appropriate for one domain (e.g. work) but not the other (Clark, 2000). Individuals used physical and temporal borders to determine the rules that make up psychological borders. Psychological borders are created as an enactment which "a process in which individuals take elements given in their environments and organize them in a way that makes sense" (Weick, 1979 as cited in Clark 2000).

3.3 Permeability

Hall & Richter (1998) define permeability as the degree to which psychological or behavioral aspects of one role or domain may enter another. For example, an individual may have an office at home whose physical doors and walls create a sort of border around his or her work. However, the border may be highly permeable because family members are accustomed to frequently entering and talking with the individual while at work (Clark, 2000).

3.4 Flexibility

Boundary flexibility is the extent to which a border may contract or expand depending on the demands of one domain or another (Clark, 2000). For example, if individuals are free to work any hours they choose, the temporal border separating work and family is flexible (Clark, 2000). Flexibility is the degree to which the spatial and temporal boundaries are pliable that is the extent to which a border may contract or expand, depending on the demands of one domain or the other (Hall & Richter, 1988). In other words, boundary flexibility is the degree to which an individual is willing and able to move from one domain (i.e., the work domain) to another domain (i.e., the family domain) to meet demands in that domain (Matthews, 2007).

Ashforth et al. (2000) indicated that 'a role with flexible boundaries can be enacted in various settings and at various times'. Mental or physical boundaries may need to be put in place. If individuals may work in any location they choose, the physical border is flexible. Similarly, when the psychological border is flexible, then an individual can think about work when at home and home when at work. Ideas, insights, and emotions flow between domains more easily when the psychological border is flexible (Clark, 2000). Therefore, flexibility refer to the ability of individuals to control over the conditions of work and family domains include having autonomy to decide how the work or house chores is to be done.

Hill et al. (2001) studied the conditions wherein spillover between the work and family domains might occur and how the two domains can impact work-family balance in terms of work flexibility. There are strong correlation between perceived work flexibility and work-family balance in his finding. Individuals with perceived work flexibility have more favorable work-family balance. They are also being able to work longer hours before they feel that their work-family balance has been compromised.

3.5 Blending

Blending occurs when high levels of permeability and flexibility exist within borders (Clark, 2000), and two domains overlap. The area around the presupposed border is no longer exclusive of one domain or the other, but blends both work and family, creating a borderland which cannot be exclusively called either domain. For example, psychological blending occurs when a person uses their personal or family experience in their work, or uses their work experience to enrich their home life.

3.6 Strength

The strength of the border can be determined by the combination of permeability, flexibility and blending. Borders that are very impermeable, inflexible and do not allow blending are strong. Conversely, borders that allow permeations, are flexible, and facilitate blending are weak. The ideal degree of border strength depends on the differences between the domains (Clark, 2000). Lambert et al. (2006) suggest that in certain situations, weak borders between work and family domains can be more beneficial in promoting balance, whereas in other situations, strong borders may be more beneficial.

3.7 The Border-Crosser

Border-crosser refers to individuals or workers who make frequent transitions between work and family domains. Border-crossers can be described based on the degree to which they are peripheral or central participants in either domain (Lave & Wegner, 1991as cited in Clark, 2000). The central participants in a domain (i.e., those who have influence in that domain because of their competence, affiliation with central members within the domain, and internationalization of the domain's culture and values) have a good ability to control the border with the other domain and, consequently, to attain a good balance between work and family. Mean while the elements of peripheral participation are contrast to the elements of central participation.

3.8 The Border-Keepers and Other Important Domain Members.

A final element of this theory involves border keepers and other domain members. Border-keepers refer to some domain members who are especially influential in defining the domain and border (e.g. spouses, supervisor etc). Other domain members may be influential in defining the domain and border, but not have power over the border-crosser (Clark, 2000).Border-keepers and other domain members play an important role in the border-crosser's ability to manage the domains and borders (Clark, 2000). Many researchers point out the existence of blurred boundaries from psychosocial factors such as the spillover of stress from work to family and situational factors such as the scheduling of home work and its location within the household (Golden et al., 2006; Hill et al., 2001; Moen & Sweet, 2002). Moreover, researchers have treated work and family life independently (Clark, 2000).

4. Developing a Conceptual Model of Managing Boundary between Work and Family

In this paper, we will use the terms "boundary" and "border" interchangeably. Based on the literature, only a few studies have examined home workers' perceptions of a blurred boundary between work and family roles; these are Ahrentzen (1990), Hill et al. (1996), Nippert-Eng (1996), and Desrochers et al. (2005). Guest (2002) suggested that the analysis of borders can illuminate the extent to which individuals are in control of issues determining balance. Such analysis opens to examination the nature of borders, their permeability, the ease with which they can be managed or moved, or so on, and allows for analysis of physical and psychological controls. This view is consistent with what Zedeck (1992) argued and is at the heart of the issue of work-family balance: the way individuals shape the scope and parameters of work and family activities, create personal meaning, and manage the relationships between families and their jobs. Igbaria & Guimaraes (1999) believe that one of the critical factors for successful teleworking is establishing clear boundaries between work and family.

Kirchmeyer (2000) views living a balanced life as achieving satisfying experiences in all life domains; doing so requires personal resources such as energy, time, and commitment to be well distributed across domains**.** This is similar to Clark's views on work–family balance, since she defines it as satisfaction and good functioning at work and at home with a minimum of role conflict (Clark, 2000). According to Kofodimos (1993), balance refers to a satisfying, healthy, and productive life that includes work, play, and love.

All these definitions of balance share two important elements. First is the notion of equality, or near-equality, between experiences in the work role and experiences in the family role (Reiter, 2007). Clark (2000), Kirchmeyer (2000), and Kofodimos (1993) imply similarly high levels of satisfaction, functioning, health, or effectiveness across multiple roles.

Second, the definitions of work–family balance implicitly consider two components of equality: inputs and outcomes. The inputs are the personal resources (Kirchmeyer, 2000) that are applied to each role. According to Kirchmeyer (2000), to be balanced is to approach each role – work and family – with an approximately equal level of attention, time, involvement, or commitment. Balance can be positive or negative; positive balance suggests an equally high level of attention, time, involvement, or commitment, whereas negative balance refers to an equally low level of attention, time, involvement, or commitment. These inputs reflect an individual's level of role engagement in terms of time devoted to each role or psychological involvement in each role. It is difficult to imagine a balanced individual who is substantially more or less engaged in the work role than in the family role. The other component of balance is the resultant outcomes that are experienced in work and family roles. One outcome frequently included in definitions of balance is satisfaction (Clark, 2000; Kirchmeyer, 2000; Kofodimos, 1993). Again, balance can be positive or negative; positive balance implies an equally high level of satisfaction with work and family roles, and negative balance suggests an equally low level of satisfaction with each role (Kirchmeyer, 2000).

Kowalski & Swanson (2005) suggest that in order to create boundaries between work and family, the teleworker can adopt strategies such as dedicating a specific space in the home for work, establishing morning rituals at home to mark the transition to a workday (e.g. dressing up as if going into the office), making dependent care arrangements for pre-school children and elderly parents, and educating family, friends, and neighbors about the telework arrangement so they know not to interrupt him during working hours. Kossek et al. (2006) stated that for professional workers to really have control over how and when they telework while also managing family demands, they may need to have a formal boundary management strategy, defined as a set of principles used to organize and separate role demands and expectations into specific realms of home (e.g. dependent care giving) and work (i.e. doing one's job) (Kossek et al., 1999).

Based on the literature review and the theoretical lens of Clark's work-family theory, we developed a conceptual framework to guide the study as shown in Figure 3-1. The study's objective is to examine the work-family balance among teleworkers achieved through the management of the border between work and home domains. The framework represents the proposed relationships among the constructs of interest in the study based on work-family border theory. The theory states that work and family are two different domains which influence each other, and that these domains are determined by borders, lines of demarcation that show the point at which domain-relevant behavior begins or ends. This border can take three forms: physical, temporal, and psychological, and can be controlled through adjusting their permeability, flexibility, blending and strength. The objective of the study is to design a border management strategy to enable individuals to attain work-family balance. Work-family balance in this study refers to individuals having a good functioning control over where, when and how they work, which in turn enables them to meet the competing demands of work and family life. A good work-family balance is achieved when an individual is able to manage their work and at the same time accomplish family satisfaction.

We will explore the strategies or practices used by the teleworker in managing physical, temporal and psychological borders. As such, we need to understand issues like where and when work and non-work activities take place, if there are borders enacted between them and how permeable and flexible these borders are. Each of the characteristics of the borders will be examined in order to answer the research questions set in this study.

(Insert Figure 3-1)

This study aims to develop a model for boundary management for teleworkers to assist them in balancing their work and family life. In particular, the research will explore how teleworkers develop their strategies for balancing work and family demands based on Clark's (2000) work-family border theory. By using Clark's theoretical lens, we hope to explain how individuals manage and negotiate the work and family spheres and the borders between them in order to attain balance. Furthermore, this theory addresses how these boundaries divide times, places and peoples that are associated with work versus family.

5. Implications

This study is expected to yield several implications. First, exploring current practices or strategies used by teleworkers will help organizations understand the consequences of new ways of working, and will enable individuals and interested parties (e.g. self-employed people) to explore innovative ways to achieve both business and personal goals. The findings from this study will contribute to the development of strategies to help individuals develop their skills in managing boundaries between work and family life.

Effective methods for managing the boundary between the two spheres could help individuals who are struggling to create harmony in the contexts of work and family life, and may strengthen and enhance their business achievement. A positive work-life environment has a positive impact on the development of this country through enhancing individuals' participation in economic activities. For example, studies have shown that through teleworking organizations can structure their operations to cut costs, maximize resources and improve productivity, develop pools of professional candidates who were physically inaccessible in the past, and by hiring workers under various contractual arrangements, including overseas employees, can offer a better quality of work and many financial benefits (Butler et al., 2007; Crandal & Gao, 2005; Gibson et al., 2002; Harpaz, 2002).

Second, providing a systematic solution means that individuals do not have to make constant choices about how to work and how to cope with the difficulties of integrating their life. This study integrates the theory and research in the examination of the role of boundary management in balancing teleworkers' work and life roles; therefore, this study contributes to the theoretical explanations of boundary management in balancing work and family, and to the understanding of the work and family issues among teleworkers.

Third, working and parenting arrangements may create further opportunities for employers, government and other related parties to make good policy decisions regarding the implementation of teleworking, and to design programs to help families find harmony between work and family life. For example, this study could be used to help shape a housing policy that promotes economic wellbeing through the development of innovative housing.

In the context of Malaysia, teleworking is a relatively new concept compared to other developed countries like the US, UK and many more. It is thus crucial for employers to change their mindset and accept that employees need not be physically present at their place of work. The goal is to improve both workplace performance and work-family life; this can be achieved only through strong support from management, in tandem with positive and effective changes in workgroup practices.

It is appealing to anticipate that teleworking will be an alternative work option for Malaysian workers, especially women, the disabled, unemployed and retired workers, remote workers, and entrepreneurs, and will allow them to generate income without creating any family and personal problems (Ministry of Women Family and Community Development, 2004). In addition, this study also contribute to creating meaningful work experiences for individuals who telework. Since teleworking is a key component of the information society, it is important for Malaysians to adapt to the changes in working styles brought about by globalization and technological advancements.

6. Conclusion

It is appealing to anticipate that teleworking will be an alternative work option for Malaysian workers, especially women, the disabled, unemployed and retired workers, remote workers, and entrepreneurs, and will allow them to generate income without creating any family and personal problems (Ministry of Women Family and Community Development, 2004). In addition, this study also contribute to creating meaningful work experiences for individuals who telework. Since teleworking is a key component of the information society, it is important for Malaysians to adapt to the changes in working styles brought about by globalization and technological advancements.

In summary, teleworking has both positive and negative impacts on teleworkers. While work and family roles often enhance one another, managing work and family demands is also a serious concern for many teleworkers. Although teleworking provides individuals with the freedom and flexibility to do their work at any time and anywhere, for some teleworkers this may give rise to work-family conflict due to the blurring of the boundaries between work and home life. This blurring makes it difficult to distinguish the work role from the family role and may lead to feelings of stress, anger, and burnout. In order to maintain the health and success of individuals and families, understanding and encouraging work-family balance is important. Different people will balance their home and work lives in different ways depending on what they value and their personal circumstances.

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Table 1. Benefits and Limitations of Teleworking

Adopted from Crandall, & Gao (2005)

	Benefits	**Limitations**
Individual	• Higher job satisfaction • Higher organizational commitment • Less pressure • Better time management • Reduced travel time • Balance work and home life • Distraction-free environment • Less involvement in office politics • Suitable for homebound employees	• Feelings of isolation from the work culture • Lack of promotional opportunities • Losing out on the assignment of good projects • Dissatisfaction with peer relationships • Less influence over the people and events at work • Work-family conflict • Harder to take sick day
Organizational	• Increased productivity • Lower costs • Less office space needed • Reduced absenteeism • Lower turnover • Do not have to have all employees in one location (natural disaster or terrorist consideration) • Increased recruitment options • Able to adapt to virtual organization	• More difficult to supervise • Assessment concerns • Special logistics requirements • Sensitive information cold be compromised • Goes against the concept of teamwork • Loss of control over health and safety • Lack of infrastructure support (secretary, etc.)
Society	• Less traffic • Less pollution • Conserve oil • Support the local and rural communities	• Fosters individualistic mentality • Fewer face-to-face relationships

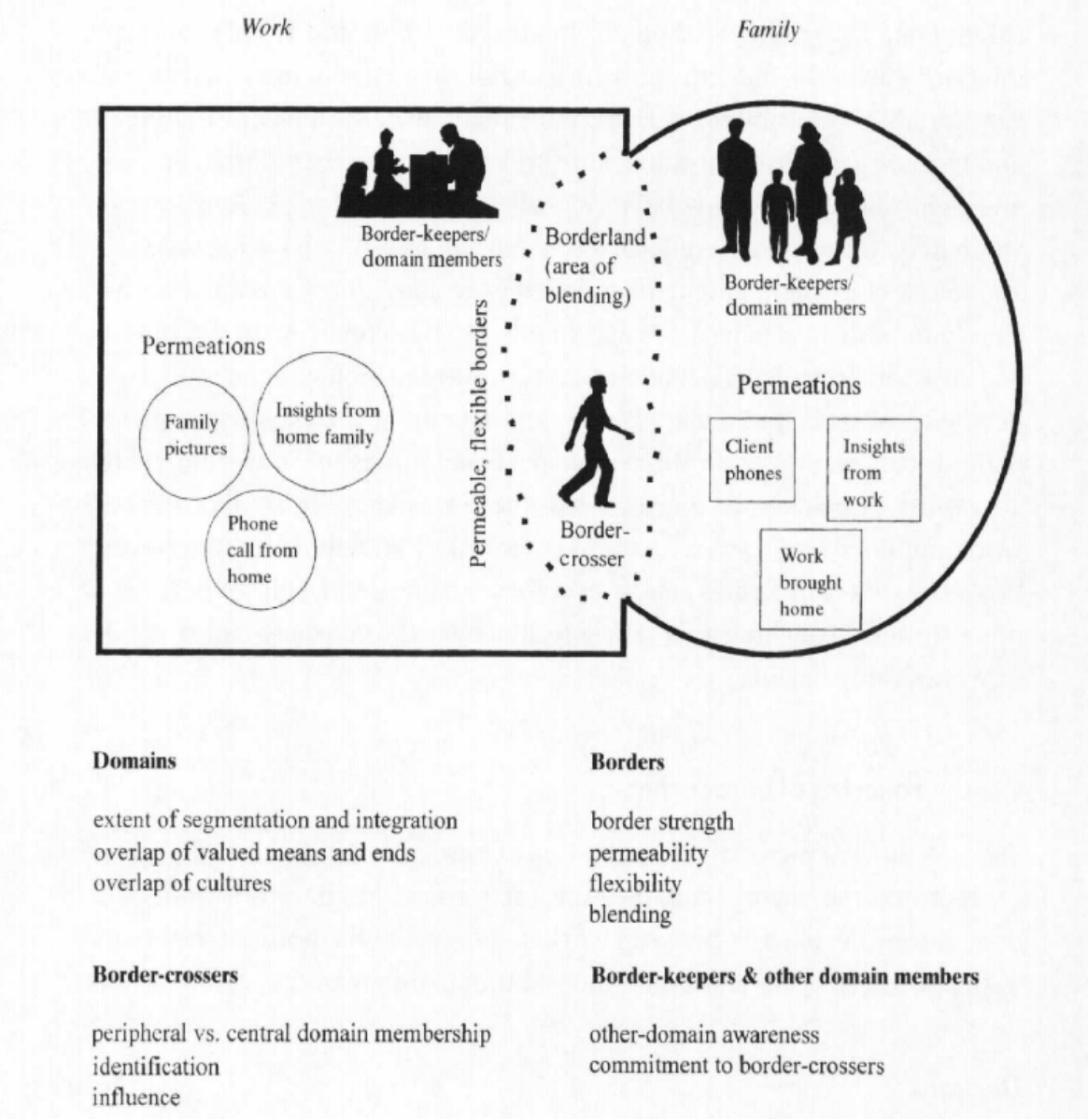

Figure 2-1. Work-family border theory (Clark, 2000)

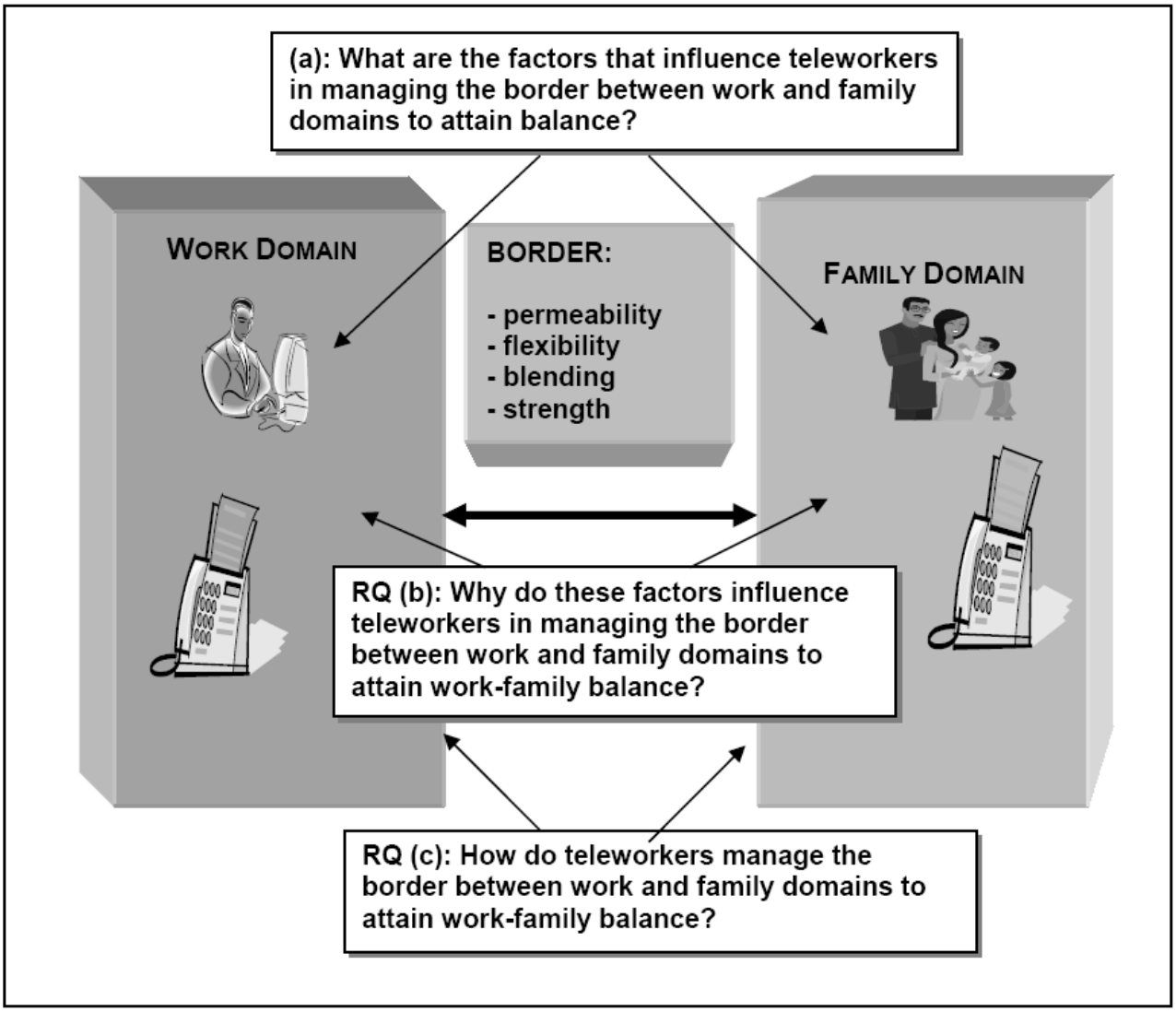

Figure 3-1. A Conceptual Framework of the Study

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Application of the Remote Sensing Technology in the Line Arrangement of Shallow Artificial Seismic Exploration

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Abstract

The remote sensing image can not only show the panorama information of the fault distribution, but also offer the information about the geology, physiognomy and digital elevation with high precision. In this paper we took the Hangzhou area as the example and systematically introduced the application of the remote sensing technology in the optimal design of the shallow artificial seismic line, and it was very important to optimize the seismic line distribution of the shallow artificial seismic exploitation, perfect the quality of the seismic materials, enhance the work efficiency and reduce the exploitation costs.

Keywords: Remote sensing image, Seismic line, Optimization design, Hangzhou

The remote sensing doesn't contact the objects, and it utilizes the visible light detector, infrared detector or the microwave detector to detect the electromagnetic wave characteristics of the objects on the earth's surface through many technologies such as photograph scanning, information induction, information transportation and information processing from the remote platform, the upper air even the outer space, and find out the natural status, the characteristics and evolvement of the object. The remote sensing image can not only subjectively, really and comprehensively offer the physiognomic characteristics, the lithology of the earth's surface, the aquosity, the loose, the attitude of stratum, the human traffic, digital elevation and 3D real-time simulation, but also reflect the information characteristics of the concealed geological structure under certain depth (Zhang, 2007, P.10-14). Combined with GPS, GIS, DEM and other technologies, the image information can offer large conveniences for the seismic prospecting and largely enhance the timeliness of the seismic exploitation.

The plain area of Hangzhou City occupies 70% of the whole city area, and most areas are covered by the Quaternary unconsolidated sediments. The region is the multiple-grown concealed fault, and according to past field seismic geological survey and the shallow artificial seismic exploration data, the active fault in the Late Pleistocene epoch through the whole region may exist in the Hangzhou area. In A.D.929, destructive earthquake of 5 magnitude happened in Hangzhou. Therefore, Hangzhou municipal government developed the work of "Hangzhou Municipal Earthquake Active fault Exploitation and Earthquake Fatalness Evaluation" in 2005 to detect whether there was the concealed active fault under Hangzhou City and evaluate the fatalness of the earthquake, and accordingly adopted the feasible measures protecting against and eliminating earthquake disasters, and offered the references for the scientific decisions of the city planning and social development. The base of the "active fault" exploitation is to detect the position of Hangzhou main fault concealed sect, the layer position and the depth of the fault, and analyze the possible activity of the fault. The application of the remote sensing image information in the line arrangement of shallow artificial seismic exploration is mainly embodied in the following aspects.

1. Optimization of seismic lines

The cost of shallow artificial seismic exploration is higher, and each kilometer construction plant needs 30,000 Yuan, and the price will be higher when the construction plant is in the city zone, because it needs large numbers of finance, manpower and material resources. To enhance the efficiency of the seismic prospecting and reduce the exploitation costs, the seismic exploitation must be deployed in the regions with the exploitation necessity and construction conditions and the distribution principle of "avoiding the highness and dwelling on the lowness, avoiding the gravel and

dwelling on the rock, avoiding the mixed and dwelling on the simply, avoiding the dry and dwelling on the wet, avoiding the steep and dwelling on the slight (Hu, 2005, P.316-317)". The remote sensing image can not only show the spacial distribution of the active fault and intuitively open out the image information of the renewed faulting, but also offering abundant information to analyze the active status of the fault and its relation with the earthquake and identify the sect of the earthquake gestation. In the concrete distribution of the seismic line, we can optimize the seismic lines for the conformation characteristics, landform characteristics, the earth's surface type and the vegetation, live up to avoid the construction difficulties brought by the highly complex landform, and complete the deployment of the seismic lines, and better control and detect the object faulting.

2. Selection of construction plants

The floor geological survey in the seismic exploitation area is the important base for the seismic engineering design, signal acquirement and data processing. It is very difficult to implement the seismic exploitation in the region of Hangzhou. First, the depth of the Quaternary covering layer in the Hangzhou area is very thin (0~100m), and in the local lots, the stone heads are bared or half bared, and they belong to the super shallow seismic exploitation, and the technical difficulty of the seismic prospecting is higher. Second, most seismic lines are in the city zone and the outskirts of Hangzhou, and in those places, the buildings are dense, the roads extend in all directions, which could not only bring inconveniences for the field construction, but the jamming is serious. Third, the short seismic section length is only about 2 kilometers, and because of the plane swing of the fault, some short sections will not span the objective fault. In addition, the Qiantangjiang River and the Great Canal traverse the Hangzhou City, which will bring certain influences for the seismic construction quality. Therefore, certain warps will exist between the seismic lines of the design in the room and the construction lines, and we need to develop the practical field geological survey before the construction. The work of field survey is large, and the labor intension is high, the work efficiency is low, the work time is long and the capital devotion is large, the comprehensive concept is lacked and the pertinence is bad and control precision is low. The high precision remote sensing image can comprehensively offer the relative distribution information about the building, the road, the vegetation and the water system, and the overlay analysis of the remote sensing image and the DEM can simulate the 3D dynamic flying exploration in the room, quickly select the construction plant and the optimal plant, avoid the disjoint of the room seismic exploitation distribution and the field seismic exploitation distribution, and avoid the bad plan of the field seismic lines distribution, and avoid influencing the selection of the shot-point and the demodulator probe and the material quality (Zhao, 2005, P.33-35).

3. Optimization of seismic observation system

The main difficulty of the seismic data field acquisition in Hangzhou is that the seismic geological condition is very complex. To obtain better original single-shot record and perfect the quality of the seismic data, we should select multiple experiments points to implement the comparison experiment about inspiring condition and accepting condition in the construction region before the construction, and ensure that the shot-points are distributed in the region with better inspiring condition.

The remote sensing image contains abundant information such as the landform elevation, the stratum attitude, the lithology of earth's surface, the physiognomy and the vegetation, and relative humidity, and by these intuitive pictures and graph information, we can realize the pre-distribution of the seismic inspiring point, the seismic accepting point, and according to the change of the inspiring point and accepting point on the earth's surface, we can timely adjust the distribution density and interval, and make the inspiring point and the accepting point distribute on the earth's surface with single lithology, low-lying and flat landform, and relatively hard surface layer, which could optimize the inspiring parameters and enhance the SNR of data. Otherwise, the exact geological coordinate data and the elevation data offered by the remote sensing data can largely offer convenient for the field construction measurement and enhance the work efficiency.

4. Optimization of seismic construction organization and logistic guarantee

The information such as areal geology, physiognomy, humanity and traffic offered by the remote sensing image can not only be applied in the seismic acquisition technological design, but also offer the information service for the seismic construction organization, the implementation equipment selection, the work risk evaluation and reasonable encampment selection, transportation lines and logistical mode. Especially under the supports of GPS, GIS and DEM, the exact 3D dynamic image can make the seismic work organization, material supply and living supply more scientific and reasonable, which will exert effective function to enhance the seismic work efficiency, reduce the inefficient devotion and control the increase of cost.

Except for that, according to the image information offered by the remote sensing image with high precision, we can exactly quantitatively confirm the surface type and the range in the seismic construction region, and the type and the quantity of the seismic equipment needed, and objectively evaluate the engineering budge of the seismic acquisition.

5. Experiment results

In the study, we took Hangzhou as the example, utilize the ETM+ satellite multiple-spectrum image, take the faults in Hangzhou as the main research objects, give prominence to the image characteristic of city fault through effective remote sensing image interpretation based on the image processing including atmospheric correction, geometric precision correction, de-noising and image enhancement, primarily confirm the position and distribution characteristics of the main faults in the region combined with the computer, and obtain the fault geology and physiognomy information in the width of 2 kilometers along the concealed fault, and the fault positioning precision is about 200m, which can offer the reference (Figure1) for distributing the line arrangement of shallow artificial seismic exploration, reduce the exploitation range, increase the exploitation points in the possible faults and enhance the exploitation precision. In the actual production, this study obtained better effect, largely enhance the work efficiency and correspondingly reduce the work cost.

6. Conclusions

Through utilizing the remote sensing image with high precision, combining with digital landform figure and DEM, adopting the exact geological information, digital elevation information, physiognomy information and surface lithology offered by the advanced remote sensing technology, and breaking through the view limitation of the field measurement, we can enhance the reasonability and the science character of the shoot-point distribution, perfect the quality of the seismic acquisition data, enhance the construction efficiency and reduce the exploitation costs.

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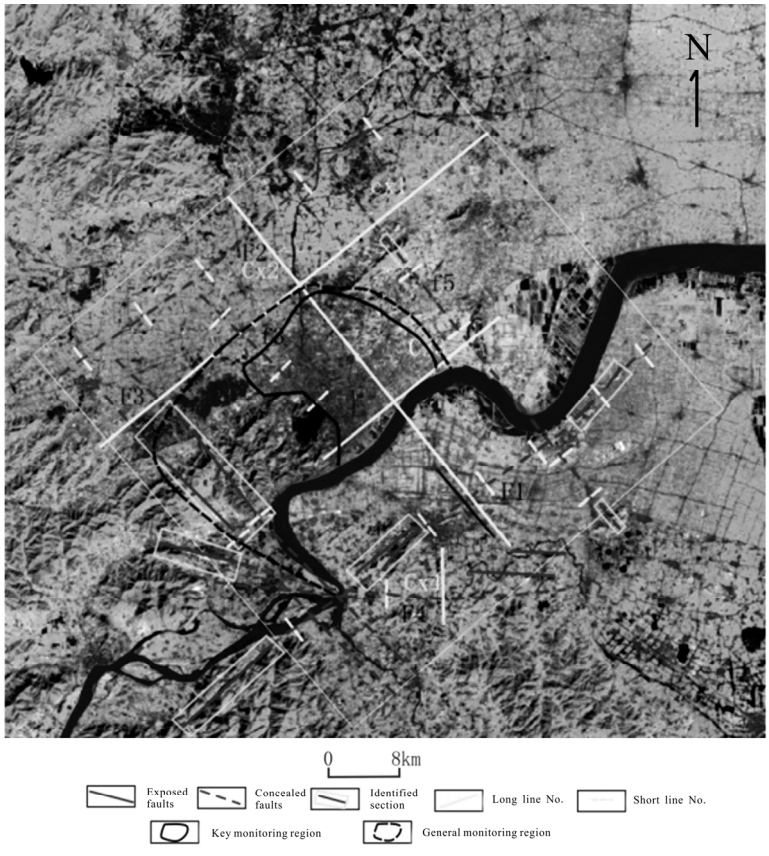

Figure 1. The Line Arrangement of Shallow Artificial Seismic Exploration in the Hangzhou Area

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Fuzzy State Space Model of Multivariable Control Systems

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Abstract

Fuzzy State Space Model (FSSM) is a new modeling technique, which was developed for solving inverse problems in multivariable control systems. In this approach, the flexibility of fuzzy modeling is incorporated with the crisp state space models proposed in the modern control theory. The vagueness and uncertainty of the parameters are represented in the model construction, as a way of increasing the available information in order to achieve a more precise model of reality. Some important properties and characteristics of FSSM were also investigated. In this paper, our discussion is focused on the formulation of the FSSM that provides algorithms for optimization of input parameters directly. The effectiveness of this modeling approach is illustrated by implementing it to the state space model of a furnace system of a combined cycle power plant. The results obtained in this application demonstrate that the proposed new modeling approach is reasonable and provides an innovative tool for decision-makers.

Keywords: Fuzzy state space model, Inverse problems, Uncertainty, Fuzzy number

1. Introduction

The design of mathematical models of complex real-world systems is essential in many fields of science and engineering. A common approach is to assume that the structure of the model is given directly as a parameterized mathematical

function, which is based on physical principles. However, for many real-world systems a great deal of information is provided by human experts, who describe the system verbally through vague, uncertain or imprecise statements. The fact that humans are often able to manage complex tasks under significant uncertainty has stimulated the search for alternative modeling and control paradigms. A typical example of techniques that make use of human knowledge and deductive processes is fuzzy modeling. Even then, most of the systems considered in literatures are single-input single-output (SISO) or multi-input single-output (MISO) systems.

Due to the complexity of most practical multivariable or multi-input multi-output (MIMO) control systems, it is necessary to develop a mathematical model of the systems by simplifying and idealizing the processes involved. Control system analysis normally addresses forward problems. However, disturbance in power systems motivate analysis questions that are classed as inverse problems (Hensel, 1991). Traditionally, such inverse problems have been addressed by repeated simulation of forward problems, for example Ordys et al (1994), Ram & Patel (1998). Thus, the objective of this paper is to present the formulation of a new modeling technique, known as Fuzzy State Space Model (FSSM). FSSM provides an algorithm that address inverse problems in multivariable control systems directly. In this approach, the flexibility of fuzzy modeling is incorporated with the crisp state space models proposed in the modern control theory. The state space formulation has been a convenient basis for the development of advanced multivariable controller design methodologies (Ogata, 1997). This is because the underlying time-domain models, which are the most natural description of most problems of interest, can address a more general class of problem definition. Besides, the state variable model of a system includes a description of the internal status of the system, in addition to the input-output behavior. To take into account the uncertainties in the model, the uncertain value parameters of the system to be controlled are represented by fuzzy numbers (Kaufmann & Gupta, 1985) with their membership function derived from expert knowledge.

The paper is organized as follows. After this introduction, section 2 describes the approaches in constructing the FSSM of multivariable control system which consider the mental, verbal and mathematical models. The development of the FSSM is described in section 3. The formulation of the Fuzzy State Space algorithm for determining the optimal parameter estimation is explained in Section 4. The validity of this algorithm is shown by implementing it to the state space model of a furnace system with three input parameters, which is presented in section 5. Finally, section 6 draws some conclusions from the presented work.

2. Approaches in model construction

A critical step in the application of model-based control algorithm is the development of a suitable model of the process dynamics. To effectively develop models, we need to blend information of different nature: experience of experts and operators, measurements and first principle knowledge formulated by mathematical equations. Thus, in the knowledge-based construction of the FSSM, the three different kinds of models considered are the mental model, verbal model and the mathematical model. From experience, intuition and expert knowledge, we build mental model in our mind. The verbal model is then formulated using "If…then…" rules, which is a very common means of description in everyday life. The verbal model can also be formulated based on fuzzy or uncertain descriptions such as "about 15", "almost 40", "around 600". The uncertain value parameters of the system are represented by triangular fuzzy numbers (TFN) that are used to analyze and manipulate approximate numeric values. TFN are used as they have an intuitive appeal and are easily specified by experts (Pedrycz, 1994). Thus, fuzzy sets serve as a smooth interface between qualitative variables and numerical domains of the inputs and outputs of the model.

For system analysis and engineering purposes, mathematical models are often constructed, for instance based on algebraic and differential or difference equations which are derived from physical laws. For well-defined systems, these standard mathematical tools lead to good models, even though the modeling process is often very tedious. However, most of the real-world systems are complex and nonlinear. Analytical approach for such systems is available only to a very limited extend (Bossel, 1994). On the other hand, a well-developed set of analytical tools is readily available for linear systems. Thus, linearization of nonlinear systems into linear state space model plays an important role. The most important advantage of the crisp state space model is that the system dynamic properties are condensed in the model (Cao & Rees, 1995). The system model gives both the external and its internal behaviour of the system. Therefore, FSSM can be seen as a modeling framework for blending information of different nature, qualitative as well as quantitative. It can adequately process not only the given data, but also the associated uncertainty.

There are two important facts that make this modeling approach intuitively appealing. Firstly, there are always uncertain factors affecting the system in a real-world modeling situation. This indicates that a complete physical model can hardly be constructed. However, uncertain factors can be taken care by employing sufficiently flexible model. Secondly, the restriction on the flexibility to comply with the prior knowledge is allowed in the modeling procedure.

3. Development of fuzzy state space model

In developing Fuzzy State Space Model (FSSM), the advantages of the white-box and black-box modeling approach are

combined. This means that the known parts of the system are modeled using physical knowledge, and the unknown or less certain parts are approximated using process data and black-box modeling structures with suitable approximation properties. Hence, FSSM exhibits some properties of the grey-box techniques. However, a great deal of information for many real-world systems, are provided by human experts who describes the system verbally through vague, uncertain or imprecise statements. Thus, the concepts from fuzzy sets (Zadeh, 1965) are used in the specification of the system's parameters, in which the parameters are fuzzy numbers instead of crisp numbers. It is interesting to note that, in this approach the input parameters can be described as approximately as desired at the early stages of the control process. This is an advantage as any early decision can restrict the set of available alternatives. The approximate description in term of uncertain input parameters is used to calculate the corresponding approximate characterization of relevant output parameters, which is then utilized to determine the optimal input parameters.

It is assumed that the multivariable dynamic system can be transformed into a solvable state space model. In state space model, the system dynamics properties are condensed in the model, which reflects its most important advantage. Besides that, it is also assumed that there is no direct transmission between the input parameters and the output parameters. Thus, FSSM of a multivariable dynamic system is defined as follows:

Definition: A Fuzzy State Space Model of a multivariable dynamic system is defined as

$$S_{gF}: \quad \dot{\boldsymbol{x}}(t) = A\,\boldsymbol{x}(t) + B\,\tilde{\boldsymbol{u}}(t)$$
$$\tilde{\boldsymbol{y}}(t) = C\,\boldsymbol{x}(t)$$

where $\tilde{u}$ denotes the fuzzified input vector $[u_1, u_2, \ldots, u_n]^{\mathrm{T}}$ and $\tilde{y}$ denotes the fuzzified output vector $[y_1, y_2, \ldots, y_m]^{\mathrm{T}}$ with initial conditions as $t_0 = 0$ and $\boldsymbol{x}_0 = \boldsymbol{x}(t_0) = 0$. The elements of state matrix $A_{p\times p}$, input matrix $B_{p\times n}$, and output matrix $C_{m\times p}$ are known to a specified accuracy.

The development of the algorithm for FSSM is based on three phases of a fuzzy system. Figure 1 shows these phases as fuzzification, fuzzy environment and defuzzification. In the first phase, each of the uncertain input parameters is fuzzified by specifying its α-cuts. For each α-cut, the possible combinations of the endpoints interval are used to calculate the induced performance parameters and the desired output parameters. All these parameters are processed by the Zadeh's extension principle (Klir & Yuan, 1995) in the second phase, to determine the associated fuzzy value that is represented by the intersection between the induced performance parameters and the desired output parameters. In the final phase, the fuzzy value is defuzzified in order to obtain the valid combination of the input parameters. Subsequently, the optimal combination of the input parameters is determined by the Extension of Optimized Defuzzified Value Theorem.

<<Figure 1. Phases in developing fuzzy algorithm>>

4. Formulation of fuzzy state space algorithm

According to Babuska and Verbruggen (1996), MIMO systems can be represented in a decomposed form as a set of coupled MISO models. Thus, the global modeling problem can be reduced to the development of fuzzy MISO models with *n* inputs and *one* output. This idea is undertaken by the formulation of the FSSM for MISO systems (Ismail et al., 2004). However, the MIMO fuzzy model which is constructed based on a group of MISO fuzzy models, will result in an increased burden of computation time (Wang, 1994). Efforts in developing a model for solving a MIMO system directly will certainly be an advantage, especially in terms of time and cost. For this reason, the Fuzzy State Space algorithm for a MISO system is enhanced to accommodate a MIMO system.

Given an input u_i that takes values in set I_i, and let preferences for different values of u_i be expressed by a fuzzy set F_{Ii} on I_i. For each $x \in I_i$, the value $F_{Ii}(x)$ designates the degree of desirability of using the particular value x within the given set of values I_i. Thus, set F_{Ii} is referred to as the set of desirable values of parameter I_i, and $F_{Ii}(x)$ is viewed as the grade of membership of value x in this set. Index i is used here to distinguish different input parameters.

The fuzzy sets expressing preference for all input parameters are employed for calculating the associated fuzzy sets for performance parameters. The target values of performance parameters are specified by functional requirements. Performance parameters, resulting from calculations with imprecise or vague input parameters, will also be represented by fuzzy preference functions. Similarly, each of the output parameters is represented by a range and a preference function. It is assumed that all the fuzzy sets F_{Ii} expressing preferences of all input parameters $u_i \in I_i \subset \Re\ (i \in \aleph)$ are determined, normalized and convex. I is a close interval of real numbers. S_{gF} is a performance parameter based on the FSSM whereby all input parameters are considered as its variables and can be presented within a fuzzy set $F_{SgF.}$ The algorithm to determine F_{ind}, a fuzzy set that is induced on the performance parameters S_{gF} has the following steps:

Step 1: Let $S_{gF}: \Re^n \to \Re^m$. S_{gF} is the performance parameter based on FSSM such that $(r_1, r_2, r_3, \ldots, r_m) = S_{gF}(u_1, u_2, u_3, \ldots, u_n)$

Step 2: Select appropriate values for α-cut such that $\alpha_1, \alpha_2, \alpha_3, \ldots, \alpha_k \in [0, 1]$ which are equally spaced.

Step 3: To fuzzify the input, determine all the α_k-cuts for all $F_{Ii}\ (i \in \aleph)$.

Step 4: Generate all 2^n combinations of the endpoints of intervals representing α_k-cuts for all $F_{Ii}\ (i \in \aleph)$. Each combination is an n-tuple (u_1, u_2, u_3,…, u_n).

Step 5: Determine $(r_1, r_2, r_3, ..., r_m)_{\alpha_i} = S_{gF}(u_1, u_2, u_3, ..., u_n)_{\alpha_i}$ for each n-tuple and for all i = 1, 2,…, k.

Step 6: With respect to α_i, find $\min(r_j)_{\alpha_i} = r_j(\alpha_{i(\min)})$ and $\max(r_j)_{\alpha_i} = r_j(\alpha_{i(\max)})$

Set $(F_{ind})_{\alpha_i} = [\min(r_j)_{\alpha_i}, \max(r_j)_{\alpha_i}]$ where i = 1, 2,…, k and j = 1,2,…, m.

Step 7: Determine all the α_k-cuts for all the desired performance parameter $F_{SgF.}$

Step 8: Generate all 2^m combinations of the endpoints of intervals representing α_k-cuts for all F_{SgF}. Each combination is an m-tuple. In this case, m = 2.

Step 9: Set $[F_{ind} \wedge F_{SgF}]$.

Step 10: Determine $f_j^* = \sup[F_{ind} \wedge F_{SgF}]$ for all j and find S_{gF}^*, the S_{gF} value of f_j^*.

Step 11: Find the endpoints of interval for each input F_{Ii} where i = 1, 2, 3,…, n.

Step 12: Generate all 2^n combinations of the endpoints of intervals representing f^*- cuts for all $F_{Ii}\ (i \in \aleph)$. Each combination is an n-tuple (u_1^*, u_2^*, u_3^*,...,u_n^*).

Step 13: Determine $r_j^* = S_{gF^*}(u_1, u_2, u_3, ..., u_n)_{fj*(opt)}$ by using the Extension of Optimized Defuzzified Value Theorem; which is stated below

Let $S_{gF} : \Re^n \to \Re^m$ where S_{gF} is a performance parameter based on the FSSM.

(a) If $S_{gF}^* = r_j^* = \max r_j$ such that $\mu(r_j^*) = f^*$ for all $(r_j, f^*) \in F_{ind}$, then $r_j^* = S_{gF}^* = \max \left\| S_{gF}(u_1^*, u_2^*, ..., u_n^*) \right\|$ where $\mu(u_i^*) = f^*$ for i = 1, 2, 3, …, n.

(b) If $S_{gF}^* = r_j^* = \min r_j$ such that $\mu(r_j^*) = f^*$ for all $(r_j, f^*) \in F_{ind}$, then $r_j^* = S_{gF}^* = \min \left\| S_{gF}(u_1^*, u_2^*, ..., u_n^*) \right\|$ where $\mu(u_i^*) = f^*$ for i = 1, 2, 3, …, n.

The theorem indicates that if the fuzzy preferred or desired parameter intersects on the maximum side of the fuzzy induced parameter, then the set of optimized parameters is the set for the maximum norm of the induced values. On the other hand, if the fuzzy desired parameter intersects on the minimum side of the fuzzy induced parameter, then the set of optimized parameters is the set for the minimum norm of the induced values. Thus, this theorem enables the decision-maker to identify the best-optimized value from predicated results in the final phase of the algorithm. It has been shown that all normal and convex fuzzy sets F_{Ii}, expressing preferences of all input parameters $g_i \in I_i \subset R^+ (i \in N)$ are mapped by the FSSM into the normal and convex induced fuzzy sets (Ismail et al., 2002).

5. Implementation to a furnace system

To illustrate the implementation of the Fuzzy State Space algorithm for MIMO system, we refer to the state space model of the furnace system developed in Ismail et al., (2005). We consider the two output parameters of the furnace system, Q_{es} (heat transferred to the economizers in J/s) and p_G (furnace air pressure in Pa). Q_{es} and p_G are also the output parameters for the boiler system of the combined cycle power plant (Ordys et al., 1994). The implementation of the Fuzzy State Space algorithm with MIMO structure is discussed according to the three phases of fuzzy system, that is, fuzzification of parameters, processing of fuzzified parameters in the fuzzy environment and defuzzification of results.

Phase 1: Fuzzification

Each of the input parameter of the furnace system is fuzzified. The desired value for each input parameter has a value α = 1 whereas the domain or the extreme values are specified as α = 0 as shown in Table 1.

<<Table 1: Input parameters specification>>

In this illustration, α-cuts with increment of 0.2 are used to calculate F_{ind}, the fuzzy values of induced output or performance parameters. Based on the steady state operating data (Ordys et al., 1994), each output parameters can be expressed as a linear combination of the input parameters. Using similar domain and desired values of the input parameters, each of the input parameter is fuzzified. α-cuts with increment of 0.2 are used to calculate F_{ind}, the fuzzy values of induced output or performance parameters. Combinations of the endpoints of intervals for all input parameters with respect to each particular value of α-cut are determined. The number of combinations increases with a smaller value of the α-cut. The induced performance parameter F_{Sg} is determined by taking the maximum and minimum value of each performance parameter. These values are used to plot the graph of $F_{Sg.}$

Similarly each of the desired output parameter is set to the values published in Ordys et al. (1994), which are obtained through forward calculations. The values for the output parameters are

$Q_{es} = [1.2 \times 10^6; 1.2465 \times 10^6, 1.4 \times 10^6]$ and $P_G = [9.0 \times 10^4; 1.013 \times 10^5, 1.2 \times 10^5]$

These values are used to calculate the preferred performance parameters. α-cuts with an increment of 0.2 as in the fuzzification of input parameters are used to calculate F_{SgF}, the fuzzy values of preferred or desired output parameters.

Phase 2: Fuzzy environment

The intersection of the fuzzy preferred output parameter and the fuzzified performance parameter is determined by superimposing the two graphs in order to obtain the f^*- value as shown in Figure 2. The largest fuzzy membership value, f_j^*, is taken if there are more than one intersection points.

Phase 3: Defuzzification

For output parameters Q_{es} and p_G of the furnace system, the fuzzy value is computed to be $f^* = 0.8141$. With the f^*-value obtained, the steps in the defuzzification process are carried out to calculate the best possible combination of the input parameters in order to accommodate the constraints defined in the process of fuzzification. With three imprecise or uncertain input parameters, there are eight possible combinations of the endpoints of interval. Each of these combinations is then substituted in the performance parameter.. The optimized input parameters are determined by using the Extension of Optimized Defuzzified Value Theorem

<<Figure 2. Fuzzy value for Furnace system (Q_{es} and p_G)>>

The results of implementation the Fuzzy State Space algorithm for a MIMO furnace system are shown in Table 2, where the optimal input parameters estimation are w_F = 12.7436 kg/s, w_A = 65.9296 kg/s and w_G = 22.5577 kg/s. These values differ from the desired values with an error of about 6.19%, 1.43% and 2.53% respectively. Using this calculated input values, the percentage error for the output parameters of the furnace system, Q_{es} and p_G, is computed to be 2.21% and 2.07% respectively. It is interesting to note that the calculated values obtained using this algorithm are very close to the desired target values of the system.

<<Table 2. Optimized input parameters>>

Subsequently, a comparison is made between the optimal input parameters obtained using the Fuzzy State Space algorithm and the result obtained through simulation carried out in Ordys et al. (1994). The percentage error is calculated and tabulated in Table 3. The aim of this comparison is to highlight the difference between inverse modeling by utilizing fuzzy sets and a widely accepted forward modeling based on simulation. With the TFN used in modeling the uncertainty, the obtained result should have the same value as the result in Ordys et al. (1994) with no uncertainty consideration. It is observed that the values of the input parameters w_F (fuel flow to the furnace in kg/s), w_A (air flow to the furnace in kg/s), and w_G (exhaust gas flow from the gas turbine in kg/s) differ with an error of 9.51%, 2.86% and 2.63% respectively. The determination of the optimal input parameters subjected to the desired output parameters can be obtained in a few computer runs, as compared to several hundreds computer runs that is required for the commonly accepted forward simulation approach. In order to properly model the uncertainties and further improve the results, the parameters of the fuzzy numbers which are used to model uncertainties in this study, need to be adjusted based on the historical data or human experience. For a better resolution, α-cuts with much smaller increment can be used.

The good results obtained in this application show that this approach may become an interesting tool for decision-makers. Besides, it is relatively easy to take into account experts knowledge and considerations for establishing the membership functions.

6. Conclusion

The formulation of the FSSM for multivariable control system was presented. The construction of this model involved the integration of three different kinds of models, namely mental model, verbal model, and mathematical model. TFN are used to represent imprecise or uncertain parameters in the model, with their membership function derived from expert knowledge. The procedure in the Fuzzy State Space algorithms involved fuzzification of all the input parameters to create fuzzy environment. This is then processed to produce the induced output parameters. The best input parameters were extracted through defuzzification using an important theorem, Extension of Optimized Defuzzified Value Theorem.

Although we have illustrated the implementation of FSSM for the furnace system of combined cycle power plant, it can be applied to any multivariable control system as long as the mathematical model of the system can be expressed in state space representation. The influence of the initially assumed uncertainties on the overall solution of the problem is reflected in the results. The determination of the optimal input parameters estimation subjected to the desired output parameters can be obtained in a few computer runs, as compared to several hundred computer runs that are required for the commonly accepted forward simulation approach. Besides that, the performance of these algorithms can be further improved by changing the initial input parameters or by reducing the α-cut increment. In general, this new technique for determination of optimal input parameters gives a broader and useful information and provides a faster and innovative tool for decision-makers.

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Table 1. Input parameters specification

input parameters	$\alpha = 0$	$\alpha = 1$	$\alpha = 0$
w_F	10	12	16
w_A	60	65	70
w_G	20	22	25

Table 2. Optimized input parameters

$f^* = 0.8141$	Calculated Values	Desired Values	Error (%)
w_F	12.7436	12	6.19
w_A	65.9296	65	1.43
w_G	22.5577	22	2.53

Table 3. Comparison of optimized input parameters

Input Parameters	Ismail's	Ordys et al.	difference (%)
w_F	12.7436	14.083	9.51
w_A	65.9296	64.093	2.86
w_G	22.5577	23.168	2.63

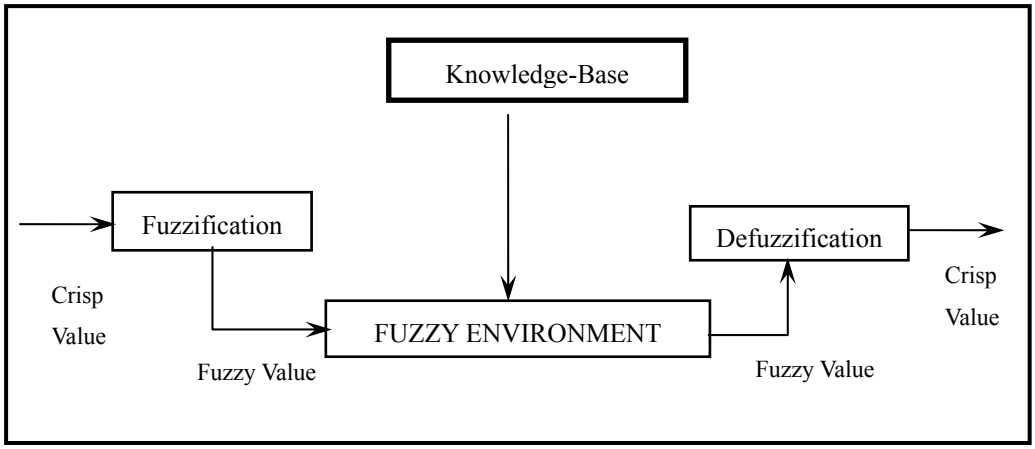

Figure 1. Phases in developing fuzzy algorithm

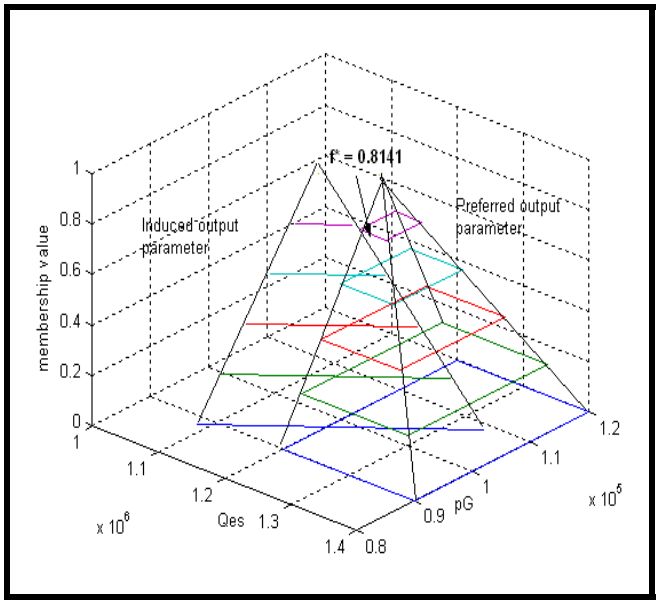

Figure 2. Fuzzy value for Furnace system (Q_{es} and p_G)

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Design of the Nonlinear System Predictor Driven by the Bayesian-Gaussian Neural Network of Sliding Window Data

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Abstract

The model identification of the nonlinear system has been concerned by the industrial community all along. The relationship of the nonlinear dynamic system is contained in the data accumulated in the scene. To better utilize the data about the industrial objects, in this article, we put forward the nonlinear system predictor driven by the Bayesian-Gaussian neural network (NN) model, use the trained threshold matrix and sliding window data to realize the online output prediction for the nonlinear dynamic system. The simulation experiment indicates that the Bayesian-Gaussian NN based on the sliding window data can fulfill the demands of the online identification and prediction of the adaptive nonlinear system.

Keywords: Sliding window data, Bayesian-Gaussian neural network, Predictor, Nonlinear

1. Introduction

Most industrial control objects are nonlinear objects with time-varying, time-lag and saturation, so the input and output relationship model of the controlled system can not be exactly established. And general classic control method is designed based on the exact model of the system, so the model is difficult to be established and many antinomies exist in many control designs. On the other hand, in the dynamic running process, much input and output data will be produced, and these data are exterior representations of the nonlinear structure characteristics of the system, and these data can help us to establish the structure model of the system.

The confirmation of the input and output nonlinear structure model of the nonlinear dynamic system is the identification problem essentially, and it is composed by the identification model with proper parameters and the performance function which adjusts the parameters through optimizing the errors between the unknown system identification and the model output (Zhang, 2000, P.566-568). The NN model is a sort of effective function approximation tool, and it has been applied in the nonlinear system identification (Li, 2001, P.499-502, Zeng, 2009, P.2293-2300, Yan, 2007, P.232-236). In theory, any three-layer forward NN can approximate any nonlinear function, but the disadvantage of the NN is that the confirmation of the hidden layer mainly depends on the experiments and experiences, and if the network weight parameters are too much, the adjustment process of the weights will get in the local minimum. Otherwise, when the structure character of the nonlinear dynamic system changes, the trained NN model always can not fit the nonlinear system after structure change, so the NN must be retrained, and the pure forward NN doesn't adapt the time-varying identification and prediction of the dynamic system.

However, in the response process of the nonlinear dynamic system, large numbers of input and output data have described the structure characters of the nonlinear dynamic system from the exterior. As viewed from the probability theory, the structure character of the dynamic system should be included in the relationship of these data. Based on Bayesian inference and Gaussian hypothesis, in this article, we put forward a sort of Bayesian-Gaussian NN reasoning model based on sliding window data which can integrate sliding window data into the structure of the reasoning model. Only through confirming same threshold matrix parameters with the nonlinear system, we can use the historical data in

the sliding window to realize the output prediction of the present system, and when the structure of the system changes, we can realize the online follow identification output of the system.

2. Description of nonlinear dynamic system

In the nonlinear dynamic system of the discrete time seen in Figure 1, suppose the system is stable, and the input and output nonlinear relationship of the system is

$$y(k) = f(y(k-1), y(k-2), \cdots, y(k-n); u(k), u(k-1), \cdots, u(k-m)) \tag{1}$$

Where, $y(k)$ denotes the output of the *k*'th step of the system, $y(k-i)$ (*i*=1, 2… *n*) denotes the system output of the former *n* steps, $u(k)$ denotes the input of the *k*'th step of the system, $u(k-i)$ (*i*=1, 2… *m*) denotes the system control inputs of the former *m* steps, *f* denotes the dynamic relationship between input and output of the dynamic system, and the nonlinear function relationship can be approximated by the identification method, and the target of the article is to use the Bayesian-Gaussian NN model based on sliding data window to approximate the structure of the nonlinear function *f* and the online identification and prediction of the dynamic system.

3. Bayesian-Gaussian NN based on sliding window data

Suppose the input vector of the nonlinear system identification model can be denotes as

$$X_k = [\hat{y}(k-1), \hat{y}(k-2), \cdots \hat{y}(k-n), u(k), u(k-1), \cdots, u(k-m)]^{\mathrm{T}} \tag{2}$$

X_k denotes the input of the system at the *k*'th sampling, and it is the column vector with *n*+*m*+1 lines. The output $Y_k = \hat{y}(k)$ is real number, and the input and output relationship of the system can denoted as

$$Y_k = f(X_k) \tag{3}$$

Based on historical input and output data, utilizing Bayesian inference and Gaussian hypothesis, the Bayesian-Gaussian model can realize the prediction $\hat{y}(k)$ of the system output $y(k)$, and the superscript "Λ" denotes the identification output of the model.

3.1 Deducing of Bayesian-Gaussian reasoning model

Suppose (X_i, y_i) (*i*=1, 2… *N*) is the sample set of the training, X_i is the sampling input of the *i*'th step, and it denotes the column vector of the m'th line, X_i=(X_{i1}, $X_{i2,\ldots\ldots}$,X_{im})$^{\mathrm{T}}$. y_i denotes the output of the system, and based on Bayesian inference and Gaussian hypothesis, the output y can be generated by the method of probability under the new input X.

3.1.1 When the single historical data (X_i, y_i) is known, what is the probability that X exports Y?

Under Gaussian hypothesis, Y possesses the probability density function p(Y) and fulfills the Gaussian normal distribution $Y \sim N(y_0, \sigma_0^2)$, where y_0 is the mean value and σ_0^2 is the variance. Suppose Y is appointed, Y_i fulfils the normal distribution $Y_i \sim N(Y, \sigma_i^2)$ and possesses the probability density function p(y_i|*Y*=*y*).

$$p(Y) = \frac{1}{\sqrt{2\pi}\sigma_0} e^{-\frac{1}{2}\frac{(Y-y_0)^2}{\sigma_0^2}} \tag{4}$$

$$p(y_i \mid Y = y) = \frac{1}{\sqrt{2\pi}\sigma_i} e^{-\frac{1}{2}\frac{(Y-y_i)^2}{\sigma_i^2}} \tag{5}$$

And the Bayesian theorem is

$$p(Y \mid y_i) = \frac{p(Y).p(y_i \mid Y)}{p(y_i)} \tag{6}$$

Substitute above (4) and (5) into (6), and simplify it and we can obtain

$$p(Y \mid y_i) = c_1 \frac{1}{\sqrt{2\pi}\sigma_{0,i}} e^{-\frac{1}{2}\frac{(Y-y_{0,i})^2}{\sigma_{0,i}^2}} \tag{7}$$

Where, c_1 is the normalization parameter, and the mean parameter $y_{0,i}$ and the variance parameter $\sigma_{0,i}^2$ can be expressed as

$$\sigma_{0,i}^{-2} = \sigma_0^{-2} + \sigma_i^{-2} \tag{8}$$

$$y_{0,i} = \sigma_{0,i}^2(\sigma_0^{-2} y_0 + \sigma_i^{-2} y_i) \tag{9}$$

3.1.2 When the historical data sample (X_i, y_i) $(i = 1,2,\cdots,N)$ is known, what is the probability that X exports Y?

Suppose the prior probability of y_i to Y is $p(Y \mid y_i)$, y_i and $y_j (i, j = 1,2,\cdots,N, i \neq j)$ are independent each other under the appointed condition Y, so the conditional probability that N data samples generate the output Y for the new input X is

$$p(Y \mid Y_1, Y_2, \cdots, Y_N) = k \frac{\prod_{i=1}^{N} p(Y \mid Y_i)}{p^{N-1}(Y)} \tag{10}$$

K is the normalization constant independent with Y and Ye Haiwen's ariticle (Haiwen Ye, 1999, P.21-36) gives the proof process in detail.

3.1.3 Bayesian-Gaussian reasoning model

Substitute (7) into (10), we can obtain

$$p(Y \mid Y_1, Y_2, \cdots, Y_N) = c_2 \frac{\prod_{i=1}^{N} \frac{1}{\sqrt{2\pi}\sigma_{0,i}} e^{-\frac{1}{2}\frac{(Y-y_{0,i})^2}{\sigma_{0,i}^2}}}{\left(\frac{1}{\sqrt{2\pi}\sigma_0}\right)^{N-1} e^{-\frac{N-1}{2}\frac{(Y-y_0)^2}{\sigma_0^2}}} \tag{11}$$

c_2 is a normalization constant independent of Y, because the distribution of the prior probability approximate as the constant, so the prior variance σ_0^2 is big, and (8) and (9) can be respectively approximated as $\sigma_{0,i}^{-2} = \sigma_i^{-2}$ and $y_{0,i} = y_i$.

Under the Gaussian hypothesis, (11) can be simplified as

$$\begin{aligned} p(Y \mid Y_1, Y_2, \cdots, Y_N) &= c_3 \frac{1}{\sqrt{2\pi}} \prod_{i=1}^{N} \frac{1}{s_i} e^{-\frac{1}{2}\frac{(Y-y_{ii})^2}{s_i^2}} \\ &= c_3 \frac{1}{\sqrt{2\pi}} \prod_{i=1}^{N} \frac{1}{\sigma_i} e^{-\frac{1}{2}\sum_{i=1}^{N}\frac{Y^2 - 2y_i Y + y_i^2}{\sigma_i^2}} \\ &= c_4 \frac{1}{\sqrt{2\pi}\sigma(N)} \prod_{i=1}^{N} \frac{1}{\sigma_i} e^{-\frac{1}{2}\sum_{i=1}^{N}\frac{(Y-y'(N))^2}{\sigma(N)^2}} \end{aligned} \tag{12}$$

In the above formula, c_4 is the normalization constant independent of Y, and the estimated mean $y'(N)$ and the variance $\sigma(N)$ are respectively expressed as

$$Y'(N) = \sigma(N)^2 \sum_{i=1}^{N} \sigma_i^{-2} y_i \tag{13}$$

$$\sigma(N)^{-2} = \sum_{i=1}^{N} \sigma_i^{-2} \tag{14}$$

Suppose the variance fulfills (15)

$$\sigma_i^{\,2} = \sigma_0^{\,2} e^{(X-X_i)^T D (X-X_i)} \tag{15}$$

In (15), D is called as the threshold matrix.

$$D = \begin{bmatrix} d_{11}^{-2} & & \\ & d_{jj}^{-2} & \\ & & d_{mm}^{-2} \end{bmatrix} \tag{16}$$

Therefore, the formulas (13), (14) and (15) composes the Bayesian-Gaussian reasoning model, and the parameters of the whole model mainly include the threshold matrix D and the initial estimation variance σ_0^2, and the dimension of the threshold matrix is equal to the input amount of the nonlinear dynamic system, so the parameters which need to be confirmed from the network are few, and the operation time of the reasoning model can be largely saved.

3.2 Bayesian-Gaussian NN

Based on above Bayesian-Gaussian reasoning model, we can obtain the Bayesian-Gaussian NN seen in Figure 2, and it adopts the nerve cell nodes (seen in Figure 3) as same as general NN, and the network includes five layers.

The first layer: Store present system input, $X = [x_1, x_2, \cdots, x_m]$.

The second layer: Store N groups historical input data samples, and each group of sample includes *m* input variables. For the *j*'th node in the *i*'th group, its input and output relationship can be expressed as

$$s_{ij}^{[2]} = x_j, \quad f^{[2]}(s_{ij}^{[2]}) = \frac{(s_{ij}^{[2]} - x_{ij})^2}{d_{jj}^2} \tag{17}$$

The superscript "[2]" denotes the second layer of the Bayesian-Gaussian NN, and the corresponding third layer and the fourth layer are denoted as "[3]" and "[4]". The threshold matrix parameter of the second layer has been included in the encouragement function. From the experiment process, the N groups of historical input data samples are very important to the prediction of the system, and to reduce the operation of the Bayesian-Gaussian NN and follow the dynamic responses on line, we adopt the sliding window data method to select the historical input data in N groups.

The third layer: In N nodes, the *i*'th node corresponds with the *i*'th input sample in the second layer, and the input and output relationship is denoted as

$$s_i^{[3]} = \sum_{j=1}^{m} \frac{(x_j - x_{ij})^2}{d_{jj}^2}, \quad f^{[3]}(s_i^{[3]}) = \sigma_0^{-2} e^{-s_i^{[3]}} = \sigma_i^{-2} \tag{18}$$

The fourth layer: Includes two nodes and the relationship of the first node and the second layer can be expressed as

$$s_1^{[4]} = \sum_{i=1}^{N} y_i \sigma_i^{-2}, \quad f_1^{[4]}(s_1^{[4]}) = s_1^{[4]} \tag{19}$$

$$s_2^{[4]} = \sum_{i=1}^{N} \sigma_i^{-2}, \quad f_2^{[4]}(s_2^{[4]}) = s_2^{[4]} \tag{20}$$

The fifth layer: Includes two nodes and the input output relationships are

$$s_2^{[5]} = \sum_{i=1}^{N} \sigma_i^{-2}, \quad f_2^{[5]}(s_2^{[5]}) = \frac{1}{s_2^{[5]}} = \sigma(N)^2 \tag{21}$$

$$s_1^{[5]} = \sum_{i=1}^{N} y_i \sigma_i^{-2}, \quad f_1^{[5]}(s_1^{[5]}) = \frac{s_1^{[5]}}{s_2^{[5]}} = y'(N) \tag{22}$$

3.3 Working procedure of Bayesian-Gaussian NN based on sliding window data

The work process can be divided into the network off-line training and the online prediction application, and the Bayesian-Gaussian NN training is mainly to confirm the threshold matrix parameter D, and the online prediction application is to predict the present system output by N groups of historical input sample, and N groups of prediction sample set adopts the sliding window method to confirm, and above two approaches can be respectively described as follows.

3.3.1 Off-line training of Bayesian-Gaussian NN

First, to the N_1 training sample (X_i, y_i), $i = 1,2,\cdots,N_1$, use the following performance evaluation function

$$V_N(D) = \frac{1}{2N_1} \sum_{i=1}^{N_1} (y_i - \hat{y}_i)^2 \tag{23}$$

Where, y_i denotes the actual system output, $\hat{y}_i$ denote other N_1-1 training samples except for X_i, use (13) and (15) to

train the Bayesian-Gaussian NN and obtain the prediction value.

The target of the train is to find out proper threshold matrix D which can make the output of actual system and the prediction value better fit, and make (23) to be least or fulfill the application precision demand of the engineering.

Above process is the process to minimize the formula (23), and we can adopt the optimization algorithm based on the grads such as the least square method and the simplex method (Yin, 2003, P.135-137, 145), and we can also adopt the genetic algorithm, the ant colony algorithm, the particle swarm optimization and other random evolutionary optimization algorithms which have been deeply researched and applied in recent years (Guo, 2003, P.70-73, Aaron, 2005, P.175-191, Susuki, 2008, P.249-253). According to the foraging process of the colon bacillus (Liu, 2007, P.991-994), we put forward the improved foraging optimization algorithm (seen in (24) and (25)), and validate they can be used to optimize these parameters through the experiment.

$$X_i^{n+1} = X_i^n + C(i)\phi(n) \tag{24}$$

$$X_i^{n+1} = X_i^n + w_1 r_1^n (P_i^{pbest} - X_i^n) + w_2 r_2^n (G^{gbest} - X_i^n) \tag{25}$$

The concrete contents and symbol parameters of the improved foraging optimization algorithm are in Liu's article (Liu, 2007, P.991-994), and in this article, we use the improved foraging optimization algorithm to optimize the threshold matrix parameter in (23), and the concrete optimization includes following six approaches.

Approach 1: Initialize relative parameters, and the approach includes optimizing the field range of the parameter θ, the step number of the chemical trend N_c, the step number of the walking operator N_s, the step length $C(i)$, the number of the species group S, the initial position of *E.Coli* X_i ($i = 1,2,\cdots,S$), the weighted coefficient w_1, w_2 and the condition that the algorithm ends in advance.

Approach 2: To every *E.Coli* individual, update the position by (23), and evaluate the adaptive function $eval_i^{n+1}$.

Approach 3: If $eval_i^{n+1} < eval_i^n$, suppose the walking counter *Counter* is 0, and keep the walking direction $\phi(n)$ unchangeable, implement the walking operator until the walking step number N_s achieves maximum or doesn't fulfill $eval_i^{n+1} < eval_i^n$. And update $Pbest_i$, P_i^{pbest}, *Gbest* and G^{gbest}.

Approach 4: If $eval_i^{n+1} > eval_i^n$, update the position of *E.Coli* by the formula (25).

Approach 5: If fulfilling the end condition, quit from the computation, or else, go on.

Approach 6: Go to the next chemical trend step.

Through above optimization process, we can obtain the threshold matrix D, and realize the training and learning process of the nonlinear dynamic system.

3.3.2 Bayesian-Gaussian NN based on sliding window data

Through above network training by the threshold matrix D, to realize the online prediction in the dynamic response process of the system, Yinli (Yin, 2003, P.135-137, 145) adopted the self-adjusted Bayesian-Gaussian NN model to sustain the constant of the number of N. Suppose there are N historical input data samples (X_i, y_i), *i*=1,2,…,*N*, when add one sample (X_μ, y_u), predict the *i*'th sample by other N samples, and compute the mean square prediction error (MSPE) of the *i*'th sample.

$$MSPE_i = E(y_i - Y_i(N))^2 + \sigma_i(N)^2 \tag{26}$$

If one sample can be predicted by other data samples, so its MSPE computed by (26) should be small, i.e. the sample can be obtained by the prediction from other samples. So we can eliminate the same from N+1 samples and keep the number of the input data samples of the online prediction unchangeable.

Above self-adjusted process of the Bayesian-Gaussian NN can bring extra computation time, especially when the input data sample number N is numerous. So the self-adjusted method has deficiencies for the online prediction application of the nonlinear dynamic system.

In this article, we use the sliding data window to confirm the input samples of Bayesian-Gaussian NN in the online prediction application. The data near the present time contribute most to the output of the present system, i.e. the data sample near the present time can predict the present output with higher precision.

The aim adopting the sliding data window is to sustain the prediction data sample scale N unchangeable for the Bayesian-Gaussian NN when predicting the output y, and the concrete method is seen in Figure 4.

Figure 4 shows three windows, and the data sample quantity of every sliding window, i.e. the width of the sliding window is N, and in the change from window 1 to window 2, only eliminate the data which is farthest to the present time of the window 1, and compose the window 2 with the data sample which is nearest to the present time, and the

change from window 2 to window 3 is similar with above process, and in this way, the sliding window data form.

4. Simulation experiments

To validate the online identification effect of the Bayesian-Gauss NN based on sliding data window, we adopt following two nonlinear dynamic systems to test.

4.1 Single input and single output nonlinear system

$$y(t) = \sin(x) + e, \quad x \in (0, 2\pi) \tag{27}$$

Where, e is the random white noise, and it is the zero mean in the experiment and its variance is 0.2. Suppose the structure of the system changes from the 320th sampling time, and it becomes into $y(t) = 2\sin(2x) + e$, and to the 450th sampling time, it becomes into the original system.

The system samples 600 numbers and the input and output curve is seen in the real line of Figure 5.

First, we use the former 300 training samples in Figure 5, and the initial parameters of the foraging optimization algorithm include S=10, N_c=200, w_1=0.3, w_2=0.2, and the initial walking step length is 0.02, and because the system is only relative wit h the input x, so there is one parameter d_{11} in the threshold matrix of the Bayesian-Gaussian NN model to be confirmed, so the parameter dimension in the foraging optimization algorithm p is 1. The threshold matrix improved by the foraging optimization algorithm D is [43.3729], and the performance index $V_N(D) = 0.0128$.

Then we utilize the improved threshold matrix parameters to dynamically predict the output of the nonlinear system, and the adopted window width N is 10, and we can obtain the following curve of broken line in Figure 5. From Figure 5, the Bayesian-Gaussian NN based on sliding window can realize the prediction and the structure change following to the dynamic nonlinear system.

4.2 Multiple inputs and single output nonlinear system

For the nonlinear dynamic system,

$$\begin{aligned} y(t) = {} & (0.8 - 0.5e^{(-y^2(t-1))})y(t-1) - (0.3 + 0.9e^{(-y^2(t-1))})y(t-2) \\ & + u(t-1) + 0.2u(t-2) + 0.1u(t-1)u(t-2) + e(t) \end{aligned} \tag{28}$$

Where, $y(t)$ denotes the system output of the present time, $y(t-i), i = 1,2$ denotes the system output of the former two steps, $u(t-i), i = 1,2$ denotes the system control input of the former steps, so the input of the Bayesian-Gaussian NN $X = [y(t-1), y(t-2), u(t-1), u(t-2)]^T$, so the corresponding threshold diagonal matrix D = diag ($d_{11}^{-1}, d_{22}^{-1}, d_{33}^{-1}, d_{44}^{-1}$). The control variable u is the random sequence which mean is 2 and its variance is 1, and $e(t)$ is the Gaussian white noise which mean is 0 and its variance is 0.04.

From the formula (28), 100 sampling numbers are taken as the training samples, and the initial parameters of the improved foraging optimization algorithm include S=20, N_c=80, w_1=0.2, w_2=0.2, and the initial walking step length is 0.01, the X of the Bayesian-Gaussian NN model include four inputs, so there are four parameters to need being confirmed, and the parameter dimension in the foraging optimization algorithm p is 4. The threshold matrix improved by the foraging optimization algorithm D=diag[28.6618, 45.5806, 36.7235, 27.7467], and the performance index $V_N(D) = 0.0247$.

From the 101st time, the system structure changes, and the input output formula is changed to the formula (29).

$$\begin{aligned} y(t) = {} & (0.8 + 0.5e^{(-y^2(t-1))})y(t-1) - (0.3 - 0.9e^{(-y^2(t-1))})y(t-2) \\ & + u(t-1) + 0.2u(t-2) + 0.1u(t-1)u(t-2) + e(t) \end{aligned} \tag{29}$$

We utilize the threshold matrix D obtained by the improved foraging optimization algorithm and select 20 as the width of the sliding data window N to implement online prediction of the system, and we can obtain the broken line output in Figure 6.

5. Analysis and conclusions

From above simulation experiment of the nonlinear dynamic system, we can see that the Bayesian-Gaussian NN based on the sliding data window can fully utilize the window data to realize the online prediction of the system and acquire better effect of the online prediction and follow. From the experiment, we can also see that the Bayesian-Gaussian NN can better adapt the structure change of the nonlinear dynamic system, because the Bayesian-Gaussian NN can integrate window data into the structure, sustainably update the structure of the network through the continual sliding of the window, and quickly capture the change of the nonlinear system structure, and this character is attractive for the dynamic system which characters change often, and it can adapt the online prediction application for the nonlinear dynamic system.

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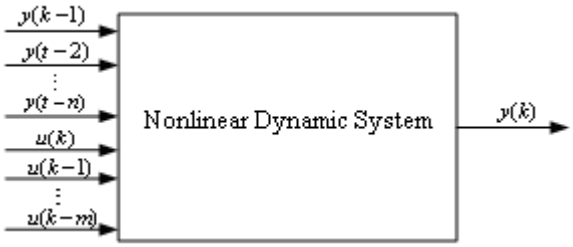

Figure 1. Nonlinear Dynamic System

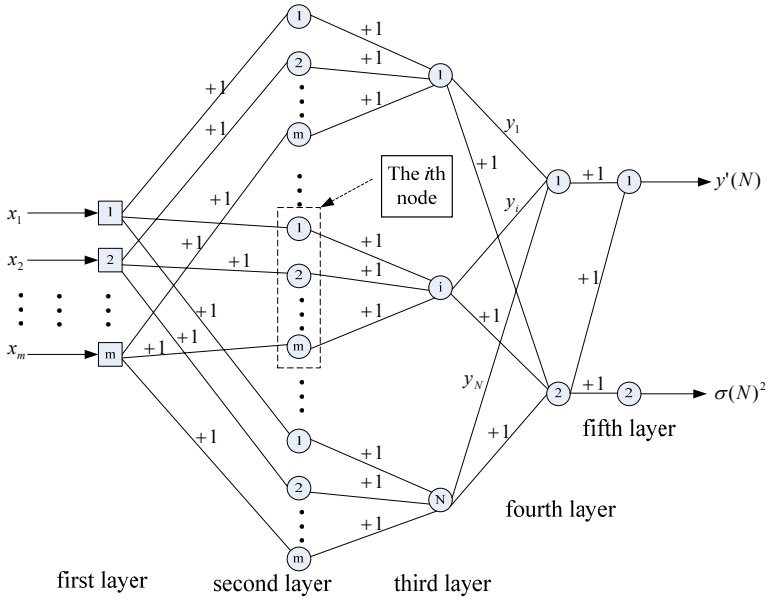

Figure 2. BGNN Network Model

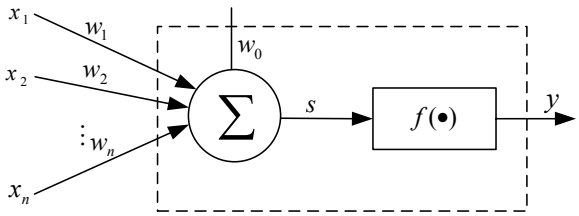

Figure 3. Nerve Cell Node Structure

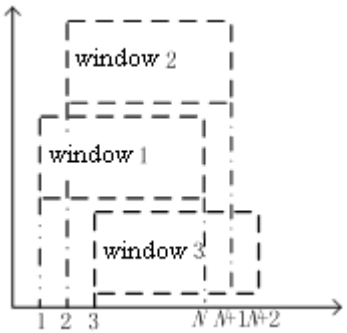

Figure 4. Work Process of Sliding Window

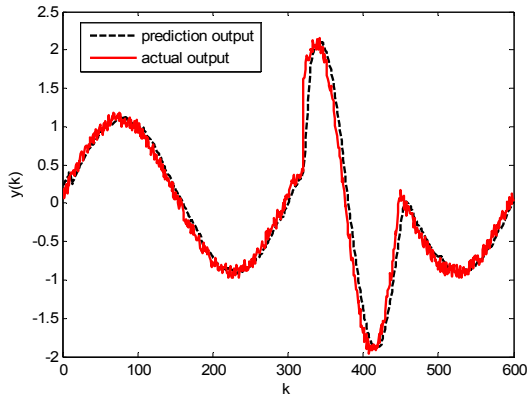

Figure 5. Online Prediction of SISO Nonlinear System

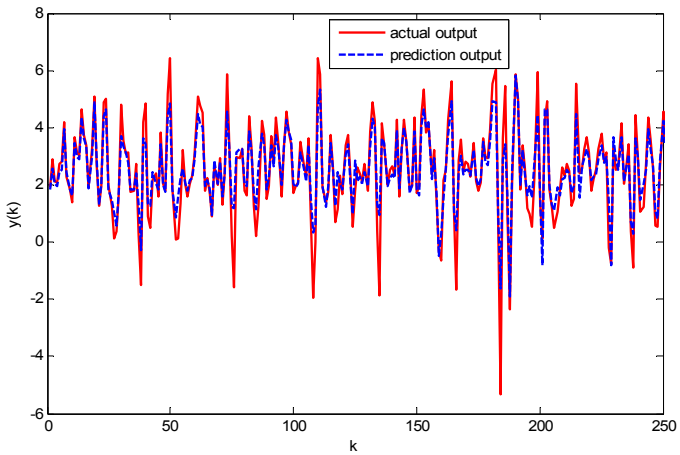

Figure 6. Online Prediction of MISO Nonlinear System

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User Evaluation of an Electronic Malaysian Sign Language Dictionary: e-Sign Dictionary

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Abstract

A software system needs to be maintained through continuous enhancements and improvements. To understand the types of enhancements to be made, a user evaluation exercise is often conducted to determine the system's weaknesses and limitations. This paper reports on the outcomes of a user evaluation survey carried out on an electronic Malaysian Sign Language Dictionary, e-Sign Dictionary. The evaluation was conducted using a questionnaire survey focusing on the functions and features of e-Sign Dictionary. A total of 45 respondents comprising deaf school teacher, deaf students, and the general public participated in the user evaluation. The results show that out of 45 respondents, 36 (81%) respondents rated e-Sign Dictionary as a good or very good system. The results of the user evaluation would be used as guidelines to enhance and improve the functions and features of e-Sign Dictionary.

Keywords: User evaluation, Malaysian sign language dictionary, e-Sign Dictionary

1. Overview of e-Sign Dictionary

e-Sign Dictionary is an electronic sign language dictionary developed for the use of the deaf community and the general public in Malaysia. It is a Windows-based system that provides instructions in English, Malay, and Chinese language. The dictionary has 500 words together with animation to illustrate the signing of each word. Each word has: explanation; illustration of its meaning with a picture (if available); synonym; antonym; and a sample sentence to illustrate its usage (Ow & Lim, 2008). The system can perform eight main functions that include allowing a system administrator to maintain the dictionary database; and users to learn Malaysian sign language with ease. Currently, the dictionary is being used by teachers and deaf students of a deaf school in Malaysia.

To evaluate the functionalities and features of e-Sign Dictionary, it is important to gather feedback and comments from the users, especially, the teachers and deaf students of the deaf school, and the general public. This paper presents the outcomes of user evaluation on e-Sign Dictionary. The feedback and comments from the users would be used as guidelines to make enhancements and improvement to the dictionary.

2. Design of user evaluation form

A few methods can be used to evaluate e-Sign Dictionary. These include: interviews which can be carried out via telephone or face-to-face; survey which can be conducted using paper-based questionnaire through the mail, or through the telephone, or through the Internet (Web-based survey) (Bourque & Fielder, 2003a; Bourque & Fielder, 2003b; DIIA assessment consulting services, 2007a); and observing the user using the system. Each method has its pros and cons. Among these methods, the survey is considered to be the most suitable as it can be used to obtain a large amount of users' feedback and comments quickly. It is also economical to conduct a survey as compared to the other methods (Fink, 2006; DIIA assessment consulting services, 2007b).

Before conducting the user evaluation survey, an evaluation form was designed. The form consists of two sections. The first section gathers the user's profile, and the second section gathers the user's evaluation of e-Sign Dictionary. The evaluation section is divided into Part A and Part B. Part A contains questions pertaining to the functions and features of e-Sign Dictionary, while Part B allows the user to suggest improvements to further enhance the functionality of the dictionary (Appendix I). A pilot test using the evaluation form was conducted. It involved 10 users. The results of the pilot test show that the questions are easy to understand and answer. Hence, the evaluation form was used in the evaluation process.

3. User evaluation process

The evaluation process involved two groups of participants. The first group comprised deaf school teacher, deaf students, and parents of a deaf student. As e-Sign Dictionary was donated to the deaf school a year ago, the teacher and the deaf students have been using it for three months or longer. The second group comprised the general public who were chosen at random during an exhibition. They were shown how to use e-Sign Dictionary to understand its functions and features, before participating in the evaluation process. The first evaluation was carried out for one week in the deaf school, and the second evaluation was carried out from 24-26 June 2008 during an exhibition. Altogether, 15 sets of evaluation forms were collected from the deaf school, and 30 sets were collected from the general public. Hence, data analyses were conducted using 45 sets of the evaluation forms. The following sections present the outcomes of the user evaluation.

4. Analyses of user evaluation

4.1 Analyses on the respondents' profiles

As shown in Figure 1, out of the 45 respondents, 22 (49%) are males and 23 (51%) are females. Of the 22 male respondents, 15, 5, 1, and 1 respondents are Chinese, Malays, Indians, and other races, respectively. On the other hand, of the 23 female respondents, 5, 14, 3, and 1 respondents are Chinese, Malays, Indians, and other races, respectively. Thus, most of the respondents are Chinese (20 respondents, 45%), and Malays (19 respondents, 42%).

As shown in Figure 2, most of the respondents are aged below 15 years (10 respondents, 22%), and between 15-20 years (15 respondents, 33%). Further analyses on these two age groups reveal that 12 (27%) of them are secondary school students, and 13 (29%) are secondary school students from the deaf school (Figure 3). Figure 3 also shows that 4 teachers participated in the user evaluation, and one of them is from the deaf school.

4.2 User evaluation on e-Sign Dictionary

i. Use of animated character feature

Four different animated characters – man, woman, boy and girl, are used to illustrate the signing of words, as shown in Figure 4 (Ow & Lim, 2008). A user can choose one of the characters to demonstrate the sign for the word. The user has the option to change the character anytime, for example, from a man character to a woman character. The boy and girl characters are provided specifically for young users (Ow & Lim, 2008). As shown in Table 1, evaluation of this feature reveals that 27 (60%) respondents agreed and 17 (38%) respondents totally agreed that the four animated characters (man, woman, boy and girl) are suitable for signing the words. Only 1 (2%) male respondent, in the 15-20 years age group, totally disagreed with the use of the animated characters. This could possibly be due to the fact that he dislikes the four characters which were developed using Poser version 6.0 (Poser 6.0, 2005), and hence, do not have natural human appearance.

ii. Search function

One of the main functions of e-Sign Dictionary is the search function. e-Sign Dictionary provides three types of search – by alphabetical order, by category, and by recent search. The categories include fruits, states in Malaysia, colours, vehicles, buildings, occupation, time and date, human body, alphabets, numbers and fractions, and emotions. Recent search allows words that have been searched previously to be repeated. Users do not need to re-type the same words again (Ow & Lim, 2008). As shown in Figure 5, evaluation of the search function reveals that 28 (63%) and 14 (31%) respondents agreed and totally agreed, respectively, that the three types of search function are sufficient. Only 3 (6%) respondents indicated that the three types of search are not enough and other search methods should be provided. The suggestions on other types of search are described in Section 5.

iii. Meaning of words

Besides providing three search methods, e-Sign Dictionary also explains the meaning of each word in text and illustrates it with a picture/photo (if available). Feedback shows that 43 (95%) respondents of all races agreed or totally agreed that the meaning of each word is clearly explained. Only 2 (5%) Chinese respondents disagreed, as shown in Figure 6. The respondents were favourable to the use of a picture/photo (if available) to illustrate the meaning of a word. In e-Sign Dictionary, words which can be illustrated using a picture/photo are nouns such as apple and house. All the respondents, irrespective of gender and race, agreed or totally agreed that the pictures/photos provided in e-Sign Dictionary help to illustrate the meaning of the word clearly (Figure 7).

iv. Synonyms and antonyms of words

In a dictionary, it is common to find the synonyms and antonyms of a word. In e-Sign Dictionary, the synonyms and antonyms are usually for adjectives such as beautiful (synonym: pretty; antonym: ugly), and adverbs such as quickly (synonym: rapidly; antonym: slowly). The outcome of the users' evaluation shows that 26 (58%) respondents agreed and 18 (40%) respondents totally agreed that providing the synonyms and antonyms of each word (if available) in

e-Sign Dictionary is useful to the learners, as shown in Figure 8. Surprisingly, 1 (2%) Malay respondent disagreed about having this feature in the system. No reason was given to support his disagreement.

v. Contents of e-Sign Dictionary

Currently, a total of 500 words are available in the dictionary. The signing of these words are based on the book entitled "Belajar Bahasa Isyarat Dalam Sepuluh Jam" (meaning: Learn Sign Language in Ten Hours) by Tan Yap, President of the Society of Interpreters of Selangor and Federal Territory, and a Malaysian Sign Language (MSL) expert (Tan, 1998). Feedback from the evaluation shows that 37 (82%) respondents agreed or totally agreed, that 500 words are sufficient for daily use by the deaf community. However, 8 (18%) respondents disagreed or totally disagreed with such an opinion, as shown in Figure 9. Most respondents suggested that more words should be included in the dictionary.

vi. Instructions displayed on the screen

When using any application system, a user often needs to interact with the system to select an option or input a value for processing. This is achieved through simple and easy to understand instructions that are displayed on the screen. As shown in Figure 10, evaluation of the instructions displayed by e-Sign Dictionary shows that 30 (67%) and 13 (28%) respondents, respectively, agreed and totally agreed that the instructions are simple and easy to understand. Only 2 (4%) respondents disagreed. On further investigation, it is found that these two male respondents are Chinese secondary students from the deaf school. It is possible that these two students might not have a good command of English and thus, have difficulty in understanding the instructions of e-Sign Dictionary.

vii. 90° rotation of the animated character

When signing a word, sometimes it is difficult to visualise the hand movement from the front view such as signing the word 'uncle,' as shown in Figure 11. e-Sign Dictionary can illustrate the signing (animation) of a word by rotating 90° to the left, or 90° to the right, as necessary. User evaluation of this 90° rotation feature reveals that 24 (63%) and 18 (31%) respondents, respectively, agreed and totally agreed that this feature helps to illustrate the signing of a word clearly. Three (7%) respondents found such rotation not to be helpful (Figure 12). Thus, this feature needs to be considered when making enhancement to the system.

viii. Zoom-in feature

As the signing of a word may appear to be too small on the screen for some users, e-Sign Dictionary has a zoom-in feature that allows a user to zoom-in on the hand of the human character to view the signing more clearly. The user evaluation of this feature shows that all respondents, except one Chinese respondent (2%), agreed and totally agreed that the zoom-in feature is necessary as it helps in viewing the signing of words clearly (Table 2). On further investigation, it is found that the respondent who disagreed with such feature is a businessman, who views the zoom-in feature as a waste of time because a user needs to zoom-out after using that function. Also, a user will not be able to view the facial expression of the human character especially for adjectives. The facial expressions are also considered a component in the signing of the words.

ix. Ease of use

One of the important issues that software developers must consider is the ease of use of a system. If users encounter difficulty when using a software, and there is no help feature, they would be inhibited from using it. Evaluation on the ease of use of e-Sign Dictionary shows that all respondents found it easy to use, except for 3 (7%) female respondents, in the 15-20 years age group, as shown in Table 3. On further investigation, it is found that these 3 respondents are deaf students of Indian ethnicity. They have been using e-Sign Dictionary for between 1-3 months only, and hence, they may need more time to familiarise themselves with it. Further interviews would be conducted with these respondents to understand the difficulties they encountered, in order to improve the ease of use of the dictionary.

5. Enhancements and improvements to *e-Sign Dictionary*

This section presents a few recommendations by the respondents to enhance and improve the functions and features of e-Sign Dictionary.

5.1 Number of words in the dictionary

Altogether, 17 respondents gave feedback on the number of words that should be stored in the dictionary. The number suggested ranges from 600 - 10 000 words, as shown in Table 4. Most (9 out of 17 respondents) suggested having 1 000 words. Unexpectedly, one secondary school student, aged below 15 years, suggested having 10 000 words in the dictionary. Only one deaf student and the deaf school teacher gave suggestions. The deaf student suggested 800 words while the deaf school teacher suggested 1 000 words. According to Tan Yap, a minimum of 800 words that are used daily would be sufficient for communication with the deaf community.

5.2 Instructions in other languages

Currently, e-Sign Dictionary provides instructions in English, Malay and Chinese language. Some respondents

suggested that including instructions in other languages would encourage other users, who do not understand these three languages but interested to learn MSL, to use e-Sign Dictionary. Table 5 shows the languages recommended by 11 respondents. These languages include: Arabic; Japanese; French; Tamil; and Iban, a language used by the Iban community in Sarawak State, Malaysia.

5.3 Additional search method

As discussed in Section 4 above, e-Sign Dictionary provides three types of search. Some respondents suggested that providing a search from sign to word would be useful to the users. Out of the 45 respondents, 16 male and 14 female respondents recommended the proposed search method. To include this type of search into e-Sign Dictionary, all the signs stored in the dictionary need to be classified into two main groups:

(a) hand orientation (i.e. the palm is facing in or facing out), and

(b) position of signing (i.e. signing in front or at the left/right side of the forehead, in front or at the left/right side of the face, in front of chest, and at the left/right side of the shoulder).

If this is done, users would be able to retrieve the word in text by choosing the sign being searched from one of the groups.

5.4 Translation of sentence from text to sign and vice versa

With the additional search method, it is possible to translate a sentence in text to an MSL sentence, and vice versa. However, feedback from the respondents shows that not all the respondents agreed to have the two-way translation. The opinions of the 45 respondents are shown in Table 6. Out of the 45 respondents, only 21 (47%) respondents suggested having a two-way translation. Thirteen (29%) respondents suggested to have translation from a sentence in text to MSL sentence, while only 3 (7%) respondents suggested the reverse translation from MSL sentence to text sentence. The remaining 8 (17%) respondents did not see the need to have translation at all. The translation from a sentence in text to MSL sentence is easy to implement as the signs can be retrieved from the database of the dictionary, and displayed according to the sequence of the words in the sentence. On the other hand, the translation in the reverse order is difficult, as a sign could have two or more meanings. Hence, the translation of a sentence in MSL to text sentence would require much more efforts to implement as a parsing algorithm needs to be formulated to correctly interpret the meanings of the sign in the context of the constructed sentence.

5.5 Appearance of the animated human characters

Although e-Sign Dictionary had received positive feedback on the suitability of using the four animated human characters to illustrate the signing of words, 21 (47%) respondents suggested that the appearance of these animated characters needs to be improved to have a Malaysian look. This would give a Malaysian identity to e-Sign Dictionary as a tool for learning MSL in a multi-racial country.

Besides the five system enhancements and improvements discussed above, 2 respondents from the general public also gave other suggestions to improve e-Sign Dictionary. One of them suggested including speech recognition into the dictionary so that instead of using the keyboard and mouse to select the words being searched, using voice input will make the system easier and more user-friendly, thus, enhancing the usability of the dictionary. Another respondent suggested that an additional window be created, specifically for showing the signing of words using the fingers.

6. Conclusion

The evaluation of e-Sign Dictionary shows that out of the 45 respondents, 36 (81%) respondents from all races, rated e-Sign Dictionary as a good or very good system. Only 8 (18%) respondents and 1 (2%) respondent rated e-Sign Dictionary as average or poor system, respectively (Figure 13). Further investigation on the respondent who rated e-Sign Dictionary as poor reveals that the respondent is a deaf student of Chinese ethnicity, in the 15-20 years age group. He finds the four animated human characters not suitable for signing words; the three types of search provided by e-Sign Dictionary are not sufficient; and also the meanings of the words are not clearly explained. Hence, he rated the dictionary as poor.

Based on the feedback and comments gathered, out of the ten functions and features reviewed in this paper, nine of them have been rated positively by between 93%-100% of the respondents. Opinions of the respondents on the contents of e-Sign Dictionary that contains 500 words, received 82% positive feedback only. Overall, the outcomes of the user evaluation provide very useful guidelines for future system enhancements and improvements. The feedback, especially from the deaf school teacher and deaf students, are much more accurate and significant than the feedback gathered from the general public. This is because the former groups use the dictionary every day, but the latter groups do not. Nevertheless, all the feedback and suggestions given by the respondents will be incorporated into e-Sign Dictionary. The revised version of e-Sign Dictionary will be updated in the deaf school, and also donated to the other deaf schools throughout the country. The design of e-Sign Dictionary makes it flexible enough to be enhanced to respond to changing user requirements over time so that it will continue to remain a useful tool for the deaf community.

Acknowledgement

The author would like to acknowledge the opinions and constructive comments of Mr. Tan Yap; the assistance and cooperation of all the respondents who participated in the user evaluation survey; and the University of Malaya which provided the research fund (Research University Grant) that enables this project to be completed successfully.

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Appendix I

Department of Software Engineering
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Section I: User Profile
Instructions: Please tick (✓) one of the options provided or specify otherwise.

Date: _____

Name: _____ (optional)

Gender: ❑ Male ❑ Female

Age Group: ❑ Below 15 ❑ 15-20 ❑ 21-25 ❑ 26-30 ❑ 31-35
(years) ❑ 36-40 ❑ 41-45 ❑ 46-50 ❑ Above 50

Race: ❑ Malay ❑ Chinese ❑ Indian ❑ Others, please specify: _____

Occupation: ❑ Teacher ❑ Student (Primary) ❑ Student (Secondary)
❑ Undergraduate ❑ Others, please specify: _____

Section II: Evaluation of e-Sign Dictionary

Purpose: To provide feedback on the user interface design, functions and features of e-Sign Dictionary. Your input will help to improve the system.

Rating Scale	
1. Totally Disagree	**3. Agree**
2. Disagree	**4. Totally Agree**

Instructions: Evaluate e-Sign Dictionary by reading the following statements, and then rate each statement using the scales given above. If your answer is "Totally Disagree," write 1 in the box provided; if it is "Disagree," write 2 in the box provided, and so on.

Part A: Use the rating scale of 1-4 to evaluate e-Sign Dictionary.	**Answer**
1. The four human characters: man, woman, boy and girl, are suitable.	
2. The three types of search: Search by alphabetical order, by category, by recent search, are sufficient.	

3. The meaning of each word is clearly explained. ☐

4. The picture/photo helps to illustrate the meaning of a word clearly. ☐

5. The synonyms and antonyms are useful to learners. ☐

6. The 500 words in e-Sign Dictionary is sufficient for communication with the deaf and for daily use. ☐

7. The instructions on the screen are simple and easy to understand. ☐

8. The 90^{o} rotation of the human character to the right or to the left helps to illustrate the signing of words clearly. ☐

9. The zoom-in feature is necessary as it helps users to view the signing of words clearly. ☐

10. e-Sign Dictionary is easy to use. ☐

11. I would like to use e-Sign Dictionary to learn Malaysian Sign Language (MSL). ☐

12. Overall rating of e-Sign Dictionary. Please tick (✓) one option only.
❑ Very Poor ❑ Poor ❑ Average ❑ Good ❑ Very Good

13. If you have used e-Sign Dictionary before, how long have you used it to learn Malaysian Sign Language? Please tick (✓) or specify otherwise.

❑ Less than 6 Months ❑ 6-9 Months ❑ 10-12 Months ❑ More than 1 year
❑ Others, please specify: _____

Part B: Tick (✓) all those items that you think are necessary to enhance the functions and features of e-Sign Dictionary.

1. Additional functions and features:
   - ❑ Increase the number of words in the dictionary. Recommended no. of words: _____
   - ❑ Include other languages. Recommended language: _____
   - ❑ Provide search from sign to word.
   - ❑ Provide translation of sentence in text to Malaysian Sign Language sentence.
   - ❑ Provide translation of sentence in Malaysian Sign Language to text sentence.
   - ❑ Improve the appearance of the human characters to have the Malaysian look.
   - ❑ Others, please specify: _____
     _____

2. Other comments, suggestions, criticisms, etc., on e-Sign Dictionary.

……

……

……

……

Thank you for your feedback and comments.

Table 1. Crosstabulation: Age group * Gender * The four human characters: man, woman, boy and girl, are suitable

The four human characters: man, woman, boy and girl, are suitable.			Gender		Total
			Female	Male	
Totally disagree	Age group	15-20	0	1	1
	Total		0	1	1
Agree	Age group	Below 15	1	1	2
		15-20	4	7	11
		21-25	4	2	6
		26-30	1	2	3
		31-35	1	2	3
		46-50	0	1	1
		Above 50	1	0	1
	Total		12	15	27
Totally Agree	Age group	Below 15	6	2	8
		15-20	1	2	3
		21-25	1	0	1
		26-30	1	1	2
		36-40	1	1	2
		41-45	1	0	1
	Total		11	6	17

This table shows the feedback of the respondents on the use of the four animated characters (man, woman, boy and girl) to sign the words. All respondents agreed or totally agreed with the use of the animated characters, except for 1 (2%) male respondent in the 15-20 years age group, who totally disagreed.

Table 2. Crosstabulation: Race * The zoom-in feature is necessary as it helps users to view the signing of words clearly

		The zoom-in feature is necessary as it helps users to view the signing of words clearly.			Total
		Disagree	Agree	Totally Agree	
Race	Chinese	1	7	12	20
	Malay	0	7	12	19
	Indian	0	2	2	4
	Others	0	0	2	2
Total		1	16	28	45

This table shows the opinions of the respondents on the zoom-in feature of e-Sign Dictionary. All respondents agreed or totally agreed on having the zoom-in feature, except for 1 (2%) respondent who disagreed to having this feature.

Table 3. Crosstabulation: Age group * Gender * e-Sign Dictionary is easy to use

e-Sign Dictionary is easy to use.			**Gender**		**Total**
			Female	**Male**	
Disagree	Age group	15-20	3	0	3
	Total		3	0	3
Agree	Age group	Below 15	2	2	4
		15-20	2	6	8
		21-25	2	2	4
		26-30	2	1	3
		31-35	1	1	2
		36-40	0	1	1
		46-50	0	1	1
	Total		9	14	23
Totally Agree	Age group	Below 15	5	1	6
		15-20	0	4	4
		21-25	3	0	3
		26-30	0	2	2
		31-35	0	1	1
		36-40	1	0	1
		41-45	1	0	1
		Above 50	1	0	1
	Total		11	8	19

This table shows the feedback of the respondents on the ease of use of e-Sign Dictionary. All respondents agreed or totally agreed that the system is easy to use, except for 3 (7%) female Indian respondents in the 15-20 years age group, who said that the system is not easy to use.

Table 4. Number of words recommended by respondents to be included in e-Sign Dictionary

		Recommended Number of words for the dictionary.								**Total**
		600	**700**	**800**	**900**	**1 000**	**1 500**	**2 000**	**10 000**	
Age groups	Below 15	0	2	0	1	1	0	1	1	6
	15-20	1	0	1	0	2	0	0	0	4
	21-25	0	0	0	0	1	0	0	0	1
	26-30	0	0	0	0	3	0	0	0	3
	31-35	0	0	0	0	0	1	0	0	1
	36-40	0	0	0	0	1	0	0	0	1
	41-45	0	0	0	0	0	0	0	0	0
	46-50	0	0	0	0	1	0	0	0	1
Total		1	2	1	1	9	1	1	1	17

This table shows the suggestions of the respondents on the number of words that should be in e-Sign Dictionary.

Table 5. Languages recommended by respondents to be included in e-Sign Dictionary

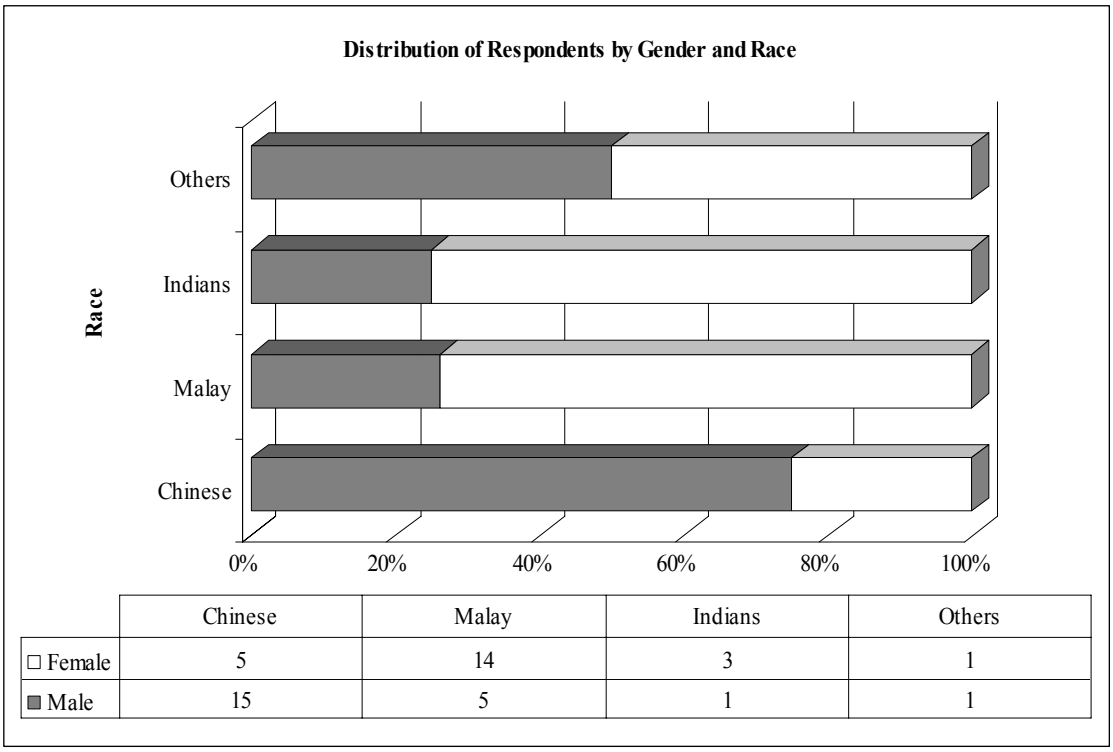
		Recommended Languages.					**Total**
		Arabic	**Japanese**	**French**	**Tamil**	**Iban**	
Age groups	Below 15	0	2	2	0	0	4
	15-20	1	0	0	1	1	3
	21-25	1	0	0	0	0	1
	31-35	1	0	0	0	0	1
	36-40	0	0	0	1	0	1
	41-45	1	0	0	0	0	1
Total		4	2	2	2	1	11

This table shows other languages suggested by the respondents to be used for the instructions of e-Sign Dictionary.

Table 6. Opinions on the translation of sentence in text to Malaysian Sign Language sentence and vice versa recommended by the respondents

Age groups			Provide translation of sentence in MSL to text sentence.		Total
			No	Yes	
Below 15	Provide translation of sentence in text to MSL sentence.	No	2	2	4
		Yes	0	**6**	6
	Total		2	8	10
15-20	Provide translation of sentence in text to MSL sentence.	No	1	1	2
		Yes	7	**6**	13
	Total		8	7	15
21-25	Provide translation of sentence in text to MSL sentence.	No	2	0	2
		Yes	1	**4**	5
	Total		3	4	7
26-30	Provide translation of sentence in text to MSL sentence.	No	2	0	2
		Yes	1	**2**	3
	Total		3	2	5
31-35	Provide translation of sentence in text to MSL sentence.	No	1	0	1
		Yes	2	0	2
	Total		3	0	3
36-40	Provide translation of sentence in text to MSL sentence.	Yes	0	**2**	2
	Total		0	2	2
41-45	Provide translation of sentence in text to MSL sentence.	Yes	0	**1**	1
	Total		0	1	1
46-50	Provide translation of sentence in text to MSL sentence.	Yes	1	0	1
	Total		1	0	1
Above 50	Provide translation of sentence in text to MSL sentence.	Yes	1	0	1
	Total		1	0	1

This table shows the opinions of 45 respondents on the translation of sentence in text to Malaysian Sign Language sentence and vice versa. Most respondents (21 respondents, 47%) suggested having two-way translation. Thirteen (29%) respondents suggested having translation from a sentence in text to MSL sentence, while only 3 (7%) respondents suggested having the reverse translation from MSL sentence to text sentence. The remaining 8 (17%) respondents did not see the need for translation.



	Chinese	Malay	Indians	Others
□ Female	5	14	3	1
■ Male	15	5	1	1

Figure 1. Distribution of Respondents by Gender and Race

This figure shows that most of the respondents are Chinese or Malays – 15 of them are male Chinese respondents, and 14 are female Malay respondents.

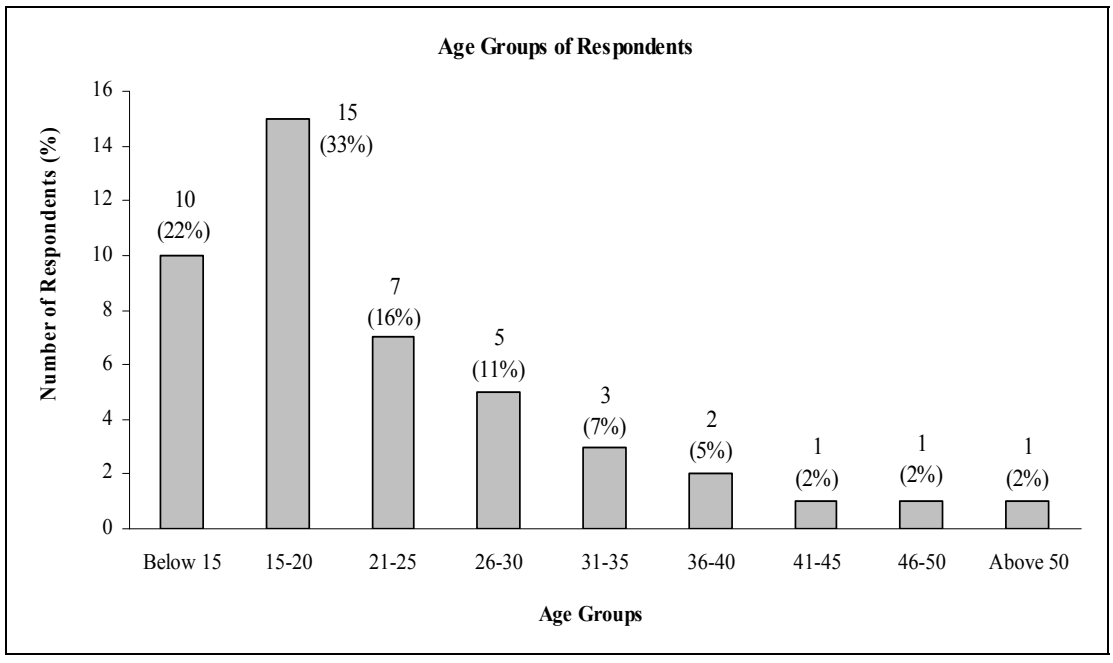


Figure 2. Age Groups of Respondents

This figure shows the distribution of respondents by age groups. Most of the respondents are of the age groups of below 15 years (22%), and 15-20 years (33%), who are presumably students.

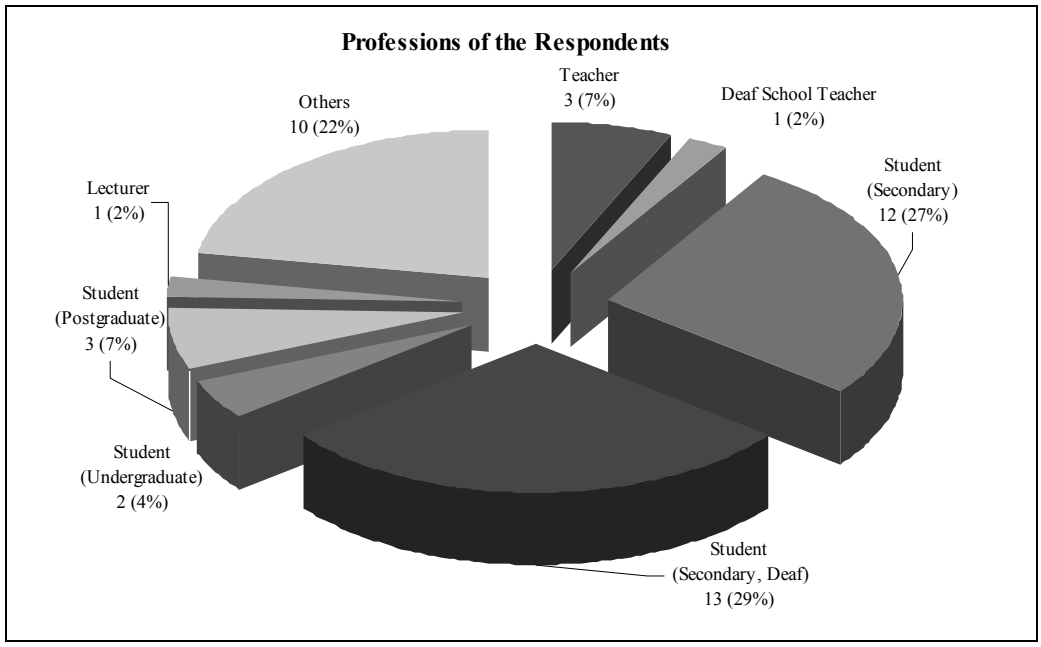


Figure 3. Professions of the Respondents

This figure shows the professions of the respondents with a majority (13 respondents or 29%) being secondary school deaf students.

Figure 4. Animated Characters for Signing Words

This figure shows the four animated human characters that a user can choose to sign a word.

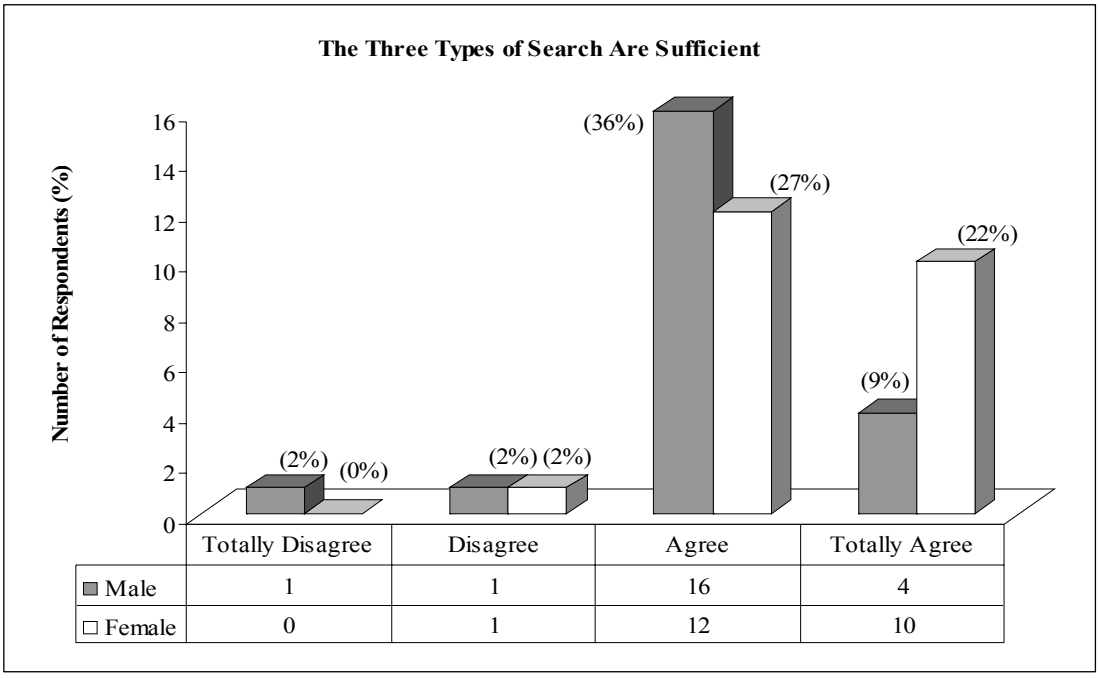


Figure 5. User's Evaluation on the Search Function

This figure shows the users' evaluation on the three types of search provided by e-Sign Dictionary. A total of 42 (94%) respondents agreed or totally agreed that the three types of search provided are sufficient.

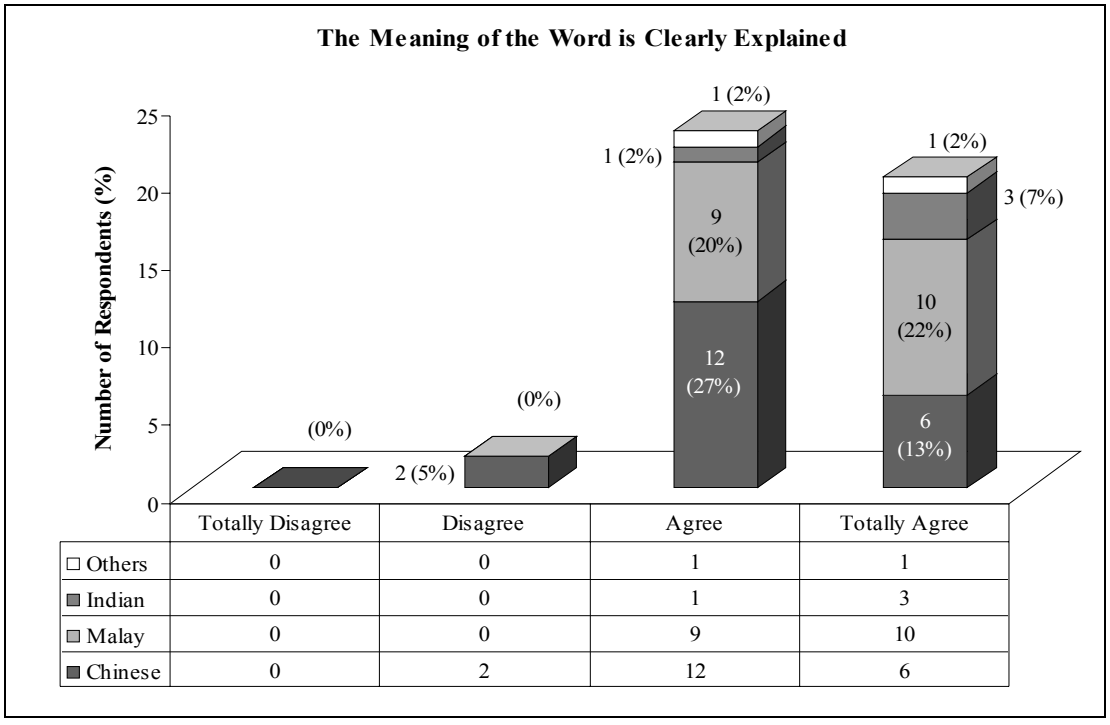


Figure 6. User's Evaluation on the Meaning of the Word

This figure shows the users' evaluation on the clarity of the meaning of each word. Out of 45 respondents, 43 (95%) respondents agreed or totally agreed on this feature. Only 2 (5%) Chinese respondents expressed that the meaning of the words are not clearly explained.

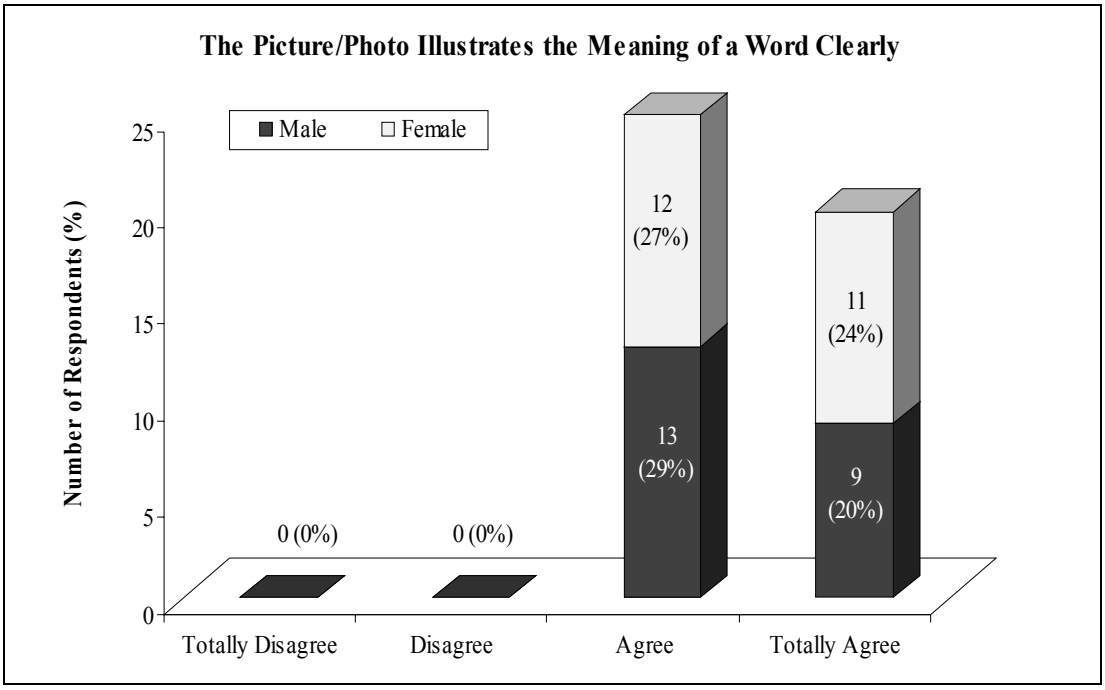
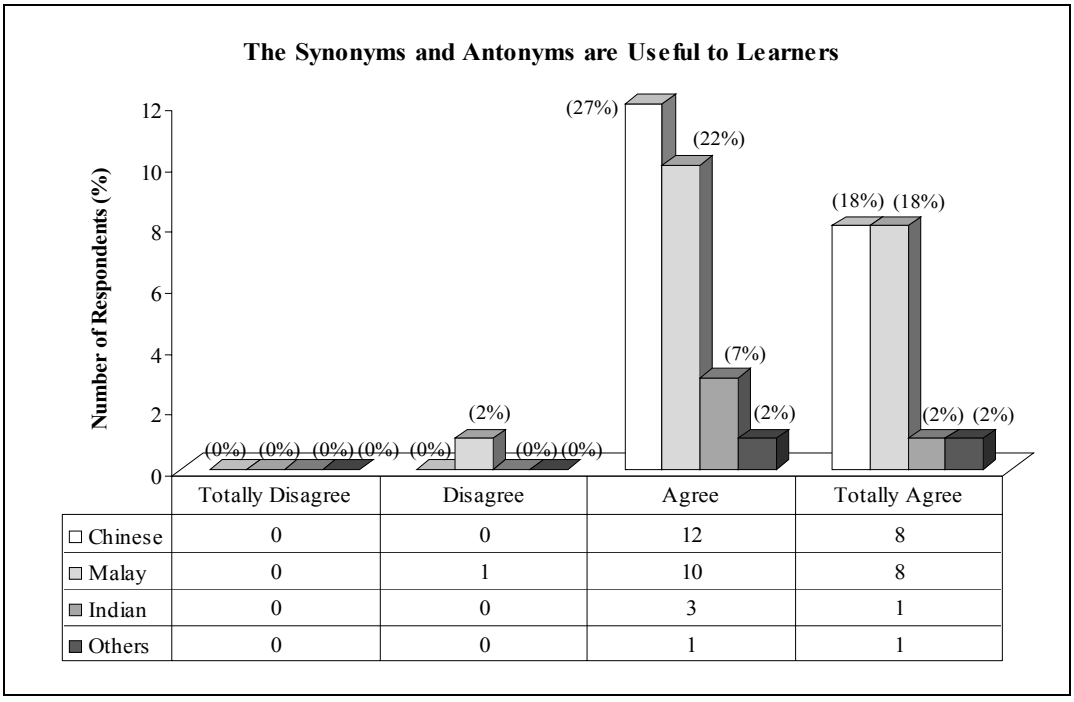


Figure 7. User's Evaluation on the Picture/Photo

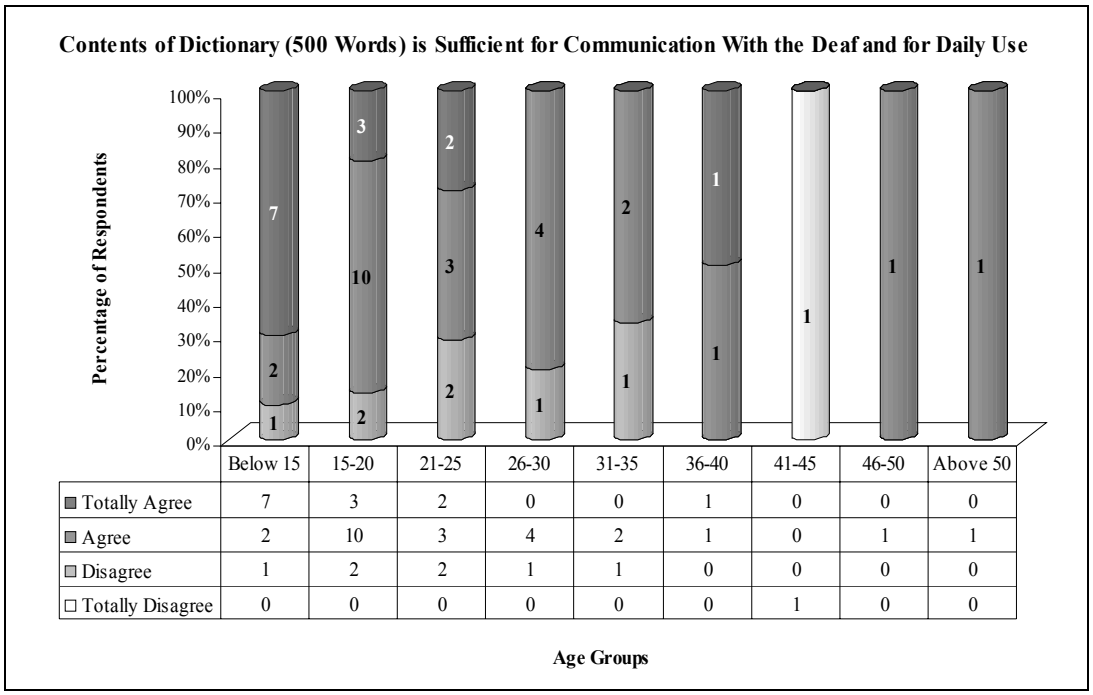
This figure shows the users' evaluation on the use of a picture/photo to illustrate the meaning of a word. All the respondents agreed or totally agreed on the usefulness of this feature.



	Totally Disagree	Disagree	Agree	Totally Agree
Chinese	0	0	12	8
Malay	0	1	10	8
Indian	0	0	3	1
Others	0	0	1	1

Figure 8. User's Evaluation on the Synonyms and Antonyms of Words

This figure shows the users' evaluation on providing synonyms and antonyms of words. Only 1 (2%) respondent does not think that this feature is useful.



	Below 15	15-20	21-25	26-30	31-35	36-40	41-45	46-50	Above 50
Totally Agree	7	3	2	0	0	1	0	0	0
Agree	2	10	3	4	2	1	0	1	1
Disagree	1	2	2	1	1	0	0	0	0
Totally Disagree	0	0	0	0	0	0	1	0	0

Figure 9. User's Evaluation on the Contents of e-Sign Dictionary

This figure shows the users' evaluation on the 500 words in the dictionary for communication with the deaf and for daily use. A majority agreed or totally agreed that the number of words is sufficient, while 8 (18%) respondents disagreed or totally disagreed.

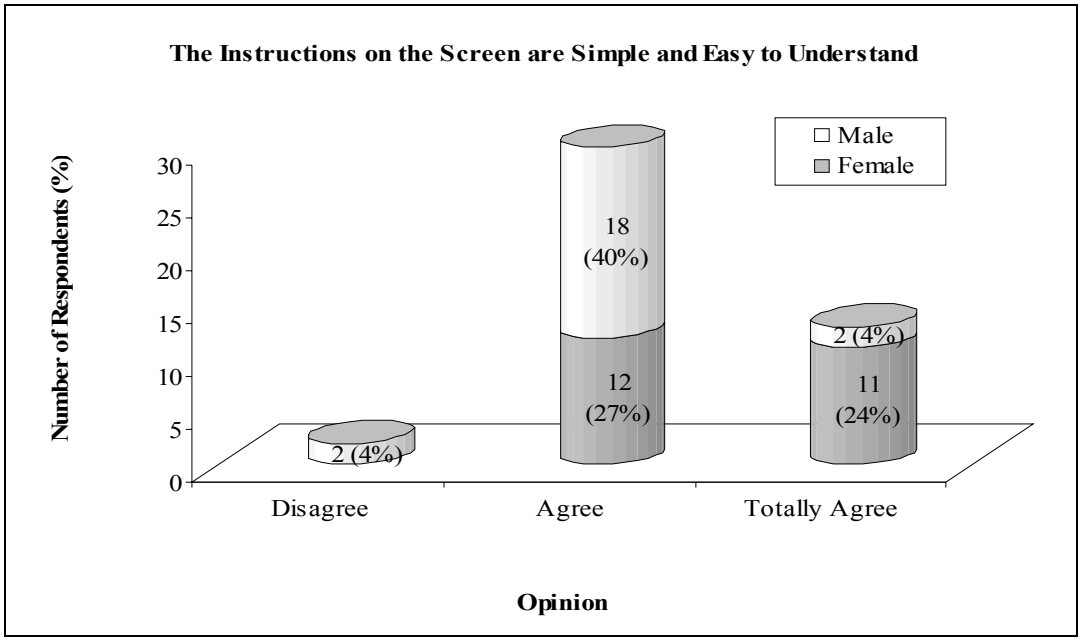


Figure 10. User's Evaluation on the Instructions Displayed on the Screen

This figure shows the opinions of the respondents on the instructions displayed by e-Sign Dictionary are simple and easy to understand. All respondents agreed or totally agreed, except for 2 (4%) male respondents from the deaf school, who disagreed with this.

Figure 11. Signing of the Word 'uncle'

This figure shows the signing of the word 'uncle,' viewed from the front, and side.

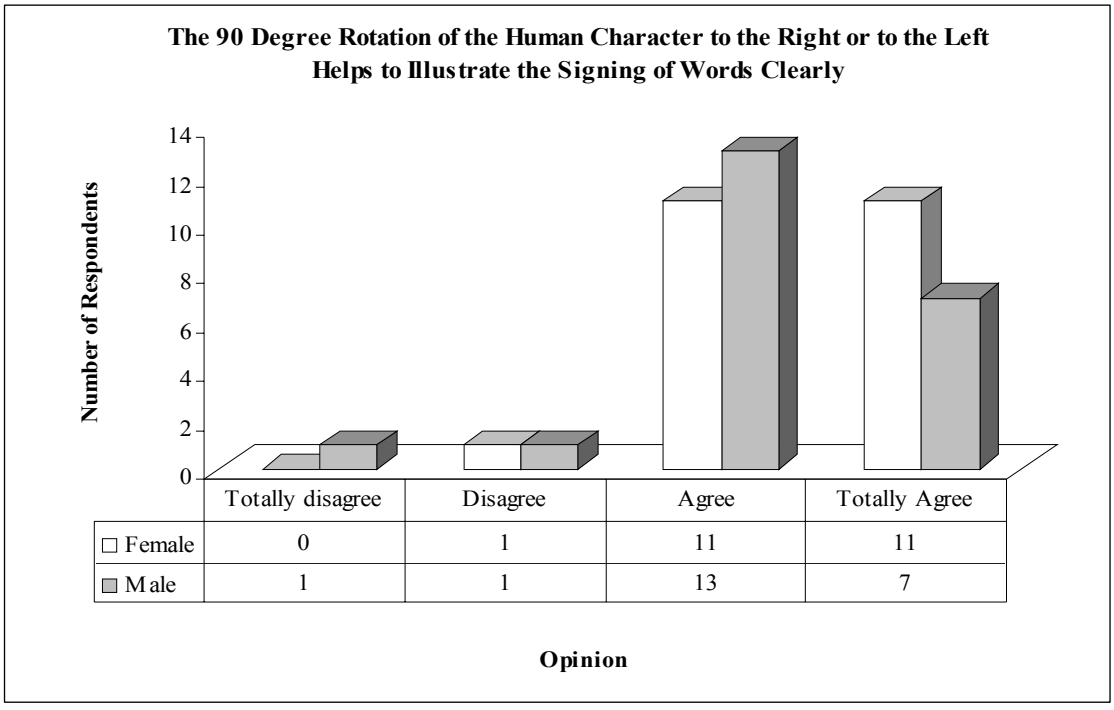


Figure 12. Opinions on the 90° Rotation of the Human Character to the Right or to the Left

This figure shows the opinions of the respondents on the 90° rotation of the human character to the right or to the left helps to illustrate the signing of words clearly. All respondents agreed or totally agreed, except for 3 (7%) respondents who disagreed or totally disagreed with this.

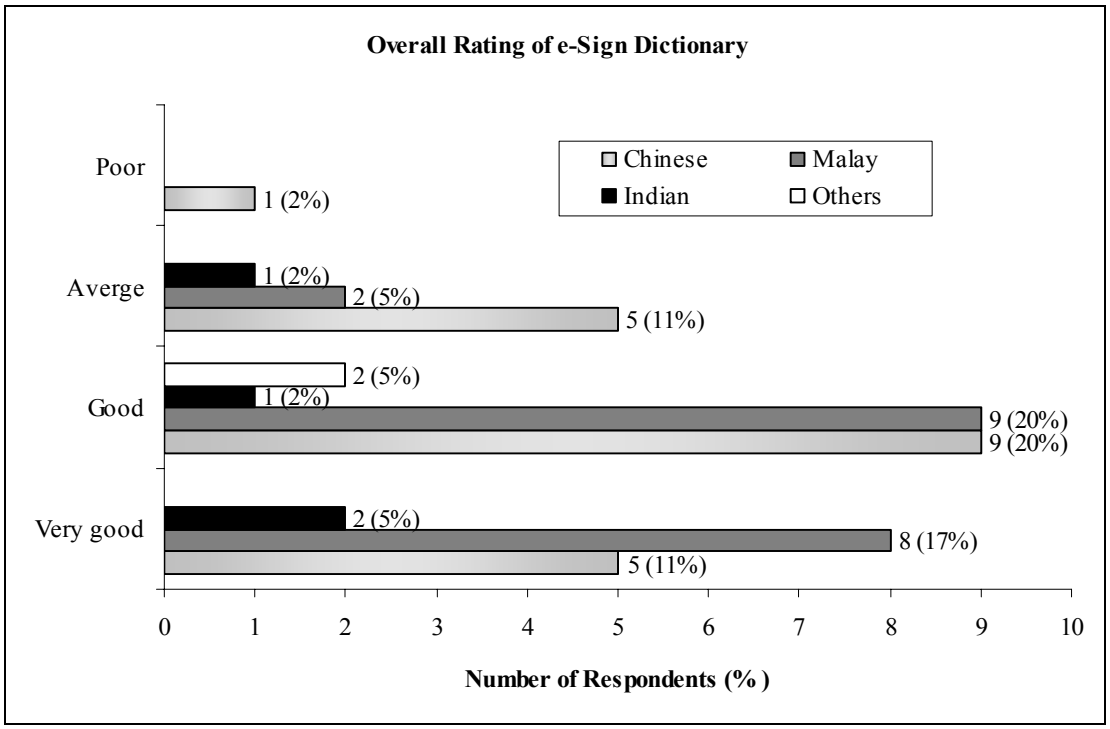


Figure 13. Respondents' Overall Rating of e-Sign Dictionary

This figure shows the overall rating of e-Sign Dictionary. A majority (36 respondents, 81%) rated e-Sign Dictionary as a good or very good system.

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Research and Establishment of the Integrated Project of Barcode Acquisition Technology and ERP System in the Regenerated Textile Chemical Fiber Industry

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Abstract

Through the research of the demand of the ERP information system of Ningbo Dafa Chemical Fiber Co., Ltd which is the leading enterprise in the regenerated textile chemical fiber industry, in this article, we put forward the solution project of the integrated logistics information system based on barcode acquisition technology and ERP system, discussed the logistics information processing flow and implementation method according with the characters of the industry, and mainly studied the implementations of barcode data acquisition method and technological project.

Keywords: Regenerated textile, Barcode acquisition, ERP, System integration

1. Introduction

Ningbo Dafa Chemical Fiber Co., Ltd belongs to the industry of regenerated chemical fiber, and it takes the reclaimed waste beverage bottle as the raw materials to produce the high-class and differential multiple functional polyester staple fiber through the waste material disposal processes such as separation, cleanout and selection and the technical processes such as melting, filter, draught and curling. Because the supply of waste plastics is sufficient and unstable, and the contents of moisture and impurity (PVC, bottle-neck and scrip) are different, which will induce the color, viscidity and melting point uneven and present dynamic change, so the variety of the waste plastics is especially numerous. At present, the automatic level of logistics management in the domestic regenerated chemical fiber industry is very low, and the industrial characters limit the extension and application of the information system in enterprises. To seek benefits from management, the company first established the standards about raw materials and finished products in the industry and introduced the Kingdee ERP management software.

To exert the function of ERP system to the largest extents and solve the bottleneck brought by the difficult data acquisition of raw materials to the cooperate management and decision-making, the company introduced the barcode system and the data acquisition model, which could solve and realize the seamless link with ERP system and produce various relative report forms, avoid the repetitive input of data, enhance the veracity and input efficiency of information, and achieve the benefit maximization of the system.

The integrated barcode information management system adopts the intranet technology, client/server (C/S) technology, database technology and ERP technology which adapt the production of Dafa Company, and takes the container batch number and packaging bag of raw materials as the main management objective, and the system can realize the functions such as the barcode conversion and print of product information, the acquisition and transmission of product data and the conversion of data, and offer the guarantee for the veracity of the data source of the ERP system. In the actual application of production practice, the system has obtained sufficient affirmation by locale operators.

2. Waste plastic processing barcode information management system

2.1 Different characters of the waste plastic processing barcode system with other barcode management systems

(1) The system can closely combine the production characters and product characters of waster plastic processing and realize the follow and management of gross slice, net slice and scrap materials. Especially aiming at the complex waste plastic classification and processing, the system establishes one soft of product organization management form, i.e. the

reasonable batch-combination and batch-division, which forms mutual and perfect solution method and develop the reasonable and feasible function module.

(2) Based on the intranet network, the system adopts three-layer C/S structure to realize the network service and sharing of product information, which can offer reliable data platform for the finance and logistics management system.

(3) According to the requirements of different clients, the system establishes its own product database and client database, which can enhance the usage efficiency of the system.

(4) The system realizes the seamless integration with ERP system by the form of second development of ERP system, which can largely reduce the operation time of data conversion.

(5) The system also realize the automatic processing function of printing forms, optimizing query and picking up data and other daily affairs, which can offer conveniences for users' daily operations.

2.2 Operation flow and total frame of the system

In the process of waste plastic processing, the barcode information management system is related with material information such as batch, size and type through ERP system, and then the collector (electric balance) acquires the weight information of every bag of waste plastic through the port of COM and transfer the information to the barcode system, and the system will print the acquired information and deliver cargos from storage or receive receipt. The data of various weights acquired in the material processing process through the electric balance can be used to analyze the flux of materials. According to the acquired data by the balance, the system will dynamic judge the start and end of once weight process, and store the weight, begin and end time, and the operator information into the database for the later query. The system implements the process according to multiple runs and multiple technical processes, and each run has its own name, and the system should record the name of the run when weighting the cargo, then the run name can be inquired later. And the run and the run name can be conveniently added and edited under the permission of limitation. Finally, the barcode system will automatically produce corresponding receiving receipt document and transfer it into the ERP system, and the concrete operation flow is seen in Figure 1.

When the system is designed, we adopt the three-layer C/S structure (seen in Figure 2), and the first layer is the user interface layer which includes data input window, data query window, data management window and form print window. The second layer is the application service layer which mainly disposes the processes such as limitation management and data processing. The third layer is the database server management layer which includes one part of storage process development and operation management (Agent) used in the data processing. The three-layer C/S structure makes the operation interface of the client port more friendly, and only simple operation can complete the management work of various data. Main data processing works are completed in the database server, and their design maintenance and updating work only need to be implemented in the database server. Because of the diversity of users (including pondering personnel, depository conservator, statistician, information center and company leaders), the system offers the multiple-user function which can implement corresponding limitation distribution aiming at different users and different management levels, and interview different operation logic models according to different limitations.

3. Design of system function

The total objective of the operation platform of the waste plastic processing product barcode information management system based on ERP system is to adopt advanced, mature, safe and reliable barcode technology to realize the acquisition of product information, and automatically combine the batches and warehouse cargos into the ERP system to implement data processing, and the system can largely enhance the warehousing entry speed of ERP system, and fulfill the special demand of enterprise logistic management. According the actual situation of waste plastic processing, the system can be divided into the basic data module, the information acquisition module, the module that statistician prints warehousing bill, the data management module and the system administrator module.

3.1 Module of base data

In the waste processing process, according the demand of raw material management, the module can introduce the size, type, product status, stock date and other information about waste plastics into the ERP, and print corresponding barcode according to the requirement of storage management.

3.2 Module of information acquisition

The information acquisition module is to acquire and automatically store the information in the stage of material processing and product production, and it is the core of the whole information acquirement system. The collector transmits the acquired information into the compute to identify and automatically record the data information through the port of COM, and judge the data according to different rules and store the information into the product database. The system implements the acquisition through the data of 8 electric balances which are divided into five work stations and 1 central management station. The system firstly sets up the port parameters and electric balance. If the type of the electric balance has existed in the system, the data in the system database can be directly transferred, which omits the

approach of setting. If the system has not the type of the electric balance, it will establish the new format which inputs the manufacturer and the type of electric balance to obtain the required data.

3.3 Module of warehousing bill print

After the electric balance weights the product, the warehouseman prints the warehousing entry bill, and the statistician completes corresponding data statistics according to the warehousing entry bill.

3.4 Module of data management

The module introduces the warehousing document batch into the ERP system through the function of data introduction, which can realize the data sharing with the ERP system and effectively enhance the using efficiency of data. In addition, the module also possesses many usual functions such as data output, data query and data processing.

3.5 Module of system function and module of employee limitation management

The module mainly implements the maintenance of the system such as modifying the users' passwords and deleting the log of the database. The personnel limitation management includes the management and operation about personnel's basic information. Through distributing different user limitation, the module can make operator to implement proper interview and operation to the various function modules in the barcode information management system only by proper mode and limitation, which can ensure the data security of the whole system.

4. Selection and design of database

The database design is the technology based on the database and its application system, and it is the important part of the development and construction of the barcode information system. Considering the ERP system which has been implemented at present in enterprises, and the characters such as the seamless integration of the barcode system with ERP system and scientific management operation flow, the database adopts the SQL Server2000 to implement development and design.

According to the method of standard design, considering the whole development process of database and its application system, the design of database is divided into six stages including demand analysis stage, concept structure design stage, logic structure design stage, physical structure design stage, database implementation stage and database running and maintenance stage. The relationship database model can be utilized to establish the corresponding relations among various tables of the database, design the table reasonably, and define the data type in the table.

5. Conclusions

The establishment and implementation of the barcode information management system which can realize the seamless link with ERP system could not only possess important actual meanings for the logistics management of Dafa Company, but largely drive the industry to further classify the waste plastics uniformly and establish feasible industrial standard. The application can also offer new idea in other processing industries which can apply the barcode into the management system to realize the seamless link with ERP system, fulfill the requirement of modern processing manufacturing and management for enterprises, strengthen the market competitive ability of enterprises to adapt the market economy with quick changes, save costs, enhance the efficiency and bring conveniences for the clients when creating large economic benefits.

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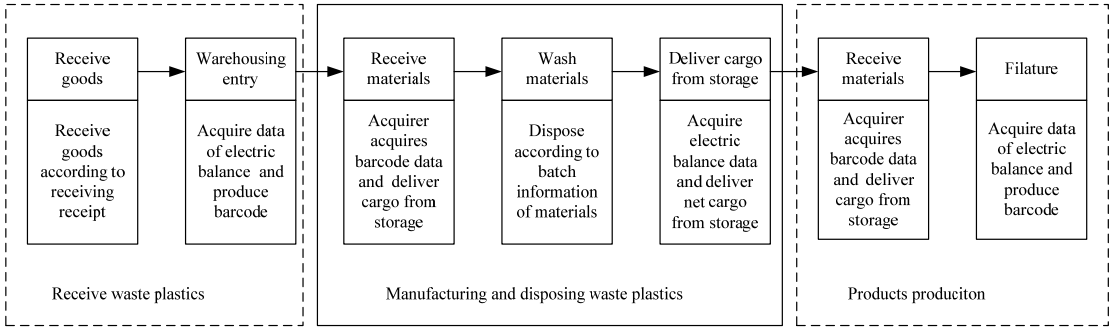

Figure 1. System Operation Flow

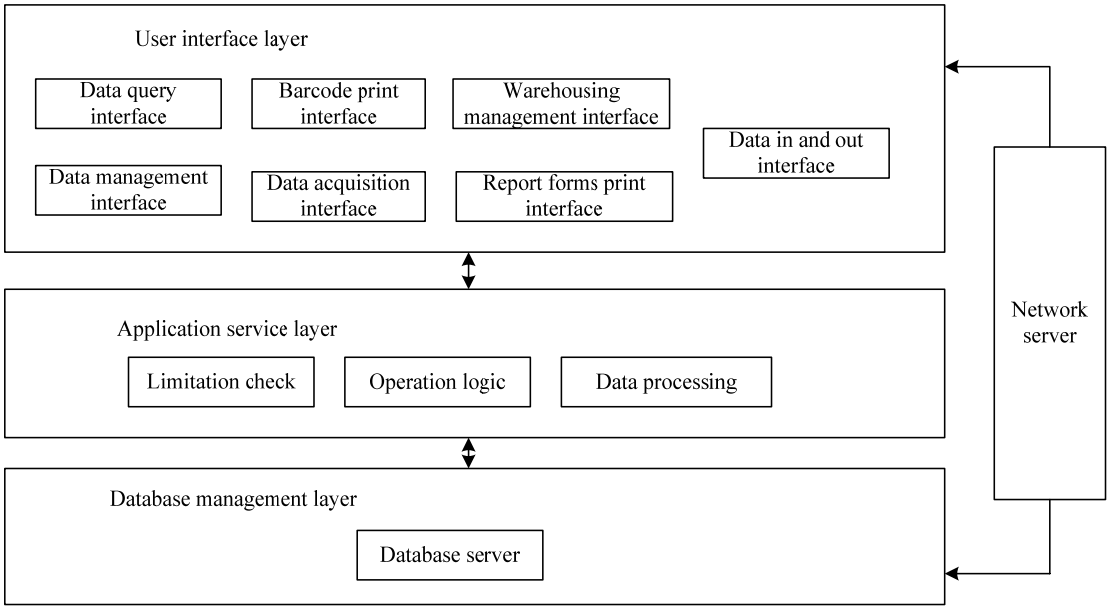

Figure 2. Frame of Waste Plastic processing Barcode Information Management System

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The Effect of Information Technology Infrastructure Flexibility on Intranet Effectiveness

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Abstract

When intranet was first conceived a decade ago, its adoption was only affordable by large business enterprise or organizations. However, at present, intranet adoption has become so prevalent that almost every organizations, irrespective of sizes and business nature has diffused intranet into their business operations and activities. While studies addressing the effectiveness of the intranet have been greatly reported in the literature, very few have really explored or focused on the antecedents or determinants to intranet effectiveness. Specifically, none has ever attempted to examine the effect of information technology (IT) infrastructure capabilities on intranet effectiveness. Against this concern, this study is an attempt to explore the relationship between IT infrastructure flexibility and intranet effectiveness. In addition, it also seeks to investigate the perceived level of IT infrastructure flexibility and intranet effectiveness in the context of public organizations in Malaysia. Based on the results of the analysis, this study has empirically showed that IT infrastructure flexibility comprising of connectivity and IT personnel are influential in determining intranet effectiveness measured in terms of operation, culture and facilitation.

Keywords: IT infrastructure flexibility, Connectivity, IT personnel, Modularity, Compatibility intranet effectiveness

1. Introduction

An Intranet is an internal information system based on Internet technology, web services, TCP/IP and HTTP communication protocols, and HTML publishing (Hinrichs, 1997). It also refers to the use of World Wide Web (WWW) servers, browsers, home pages, search engines and hyperlinks, file transfer facilities, and management tools within an organization (Muraszkiewicz, 1996). At present intranet technologies have significantly matured and has undergone diverse advancements and sophistications. In fact, to reflect these complexities, new terms such as portal or enterprise portal have been coined to replace intranet. Also, its implementation has become so prevalent that almost every organizations, irrespective of sizes and business nature has diffused intranet into their business operations and activities. In particular, its adoption among public and non-profit organizations is also very common driven by the benefits and advantages associated with its implementation.

As intranets being deployed and implemented into business organizations, studies addressing its effectiveness has and will continue to capture the interest of many IS scholars and researchers alike. However, despite the many studies that addressed intranet effectiveness in diverse implementation settings, very few have really explored or addressed the antecedents or determinants of intranet effectiveness (Masrek, Karim & Hussein, 2007). As noted by Delone & Mclean (2002), when studying information system (IS) effectiveness, one should concentrate on its antecedents or predictors which might include various contextual and demographic factors affected by environmental, organizational, technological and individual traits.

Such studies are certainly important as that would further deepen our understanding on factors that contributes towards the success of the intranet. Findings of such studies would also assist intranet implementers to devise plans and undertake necessary actions as that would further help to improve their intranet effectiveness. Likewise, the findings of this study should be helpful to future intranet adopters as that will provide guidance to them on factors that must be emphasized in the course of running successful intranet systems. Furthermore, considering that intranet is not an

inexpensive technological investment, any organization implementing it would expect better return on its investment. Against this concern, this study is an attempt to examine the relationship between technological factors i.e. IT infrastructure flexibility and intranet effectiveness.

Given that this factor has been shown to be influential in determining IS effectiveness or business performances in numerous IS studies, little is really known as to whether this factor is also applicable in the context of intranet implementations. Furthermore, study addressing both IT infrastructure flexibility and intranet effectiveness has yet to be done in the context of developing country such as Malaysia. To this effect, not much is really known on the level of IT infrastructure flexibility and intranet effectiveness of organizations in Malaysia. In addition to the aforementioned purposes, the study is also meant to validate the instrument of intranet effectiveness developed by Murgolo-Poore *et al.* (2002)

2. The research model

In studies researching IS effectiveness, the IS success model developed by Delone & Mclean (1992) has always been the favorite choice amongst IS researchers. In the decade prior to its updating, Delone & Mclean (2003) identified that its original model had been cited by 285 refereed articles on journals and proceedings. The model defines IS effectiveness as the inter-relationship of six dimensions namely information quality, system quality, IS use, user satisfaction, individual impact and organizational impact. Consequently, Myers, Kappelman & Prybutok (1998), updated the original IS success model to include workgroup impact and service quality. Previous studies have shown that in adopting the IS success model for studying IS effectiveness, researchers have either partially or fully adopted all of the dimensions. When studies were done at the firm level perspectives, researchers would usually give priority on investigating on workgroup impact and organizational. Delone & Mclean (1992) argued that the IS success model was meant to provide the independent variables and thus future studies intending to adopt the model should consider investigating the contributing factors of determinants.

Studies from Ang *et al*. (2001) and Hussein *et al.* (2007) empirically showed that technological factors were critical in determining IS/IT effectiveness. Focusing on IT infrastructure flexibility as the technological factors, Saaksjarvi (2000); Chung, Rainer & Lewis (2003), Chung *et al.* (2005), and Ness (2005) further confirmed that IT infrastructure flexibility was influential in predicting IS/IT effectiveness. In the domain of intranet studies, Eder & Igbaria (2001) noted that flexible IT infrastructure should provide a foundation that is less complex, hence facilitating the implementations of intranet applications and its service offerings. Their study hypothesized and empirically showed that IT infrastructure flexibility was strongly associated with intranet infusion. Following their findings, Masrek, Karim & Hussein (2007) also conceptualized that IT infrastructure flexibility is a predictor of intranet effectiveness. Based on the aforementioned discussion, this study hypothesizes that IT infrastructure flexibility which consists of compatibility, connectivity, modularity and flexible IT personnel (Byrd & Turner, 2000; Tallon & Kreamer, 2003) will be significantly related to intranet effectiveness measured in terms of operation, culture and facilitation (Murgolo-Poore *et al.* 2002). Accordingly, a research model as shown at Figure 1 is proposed.

2.1 Intranet effectiveness

The effectiveness of an intranet is always associated with the benefits for its implementation. Various studies have empirically demonstrated the benefits and merits of intranet adoption both at the firm level and individual level perspectives. Benefits at the firm level perspectives relates to the effect of intranet on organizational performances such as productivity improvements, cost savings, and enhanced customer service (Lai & Mahapatra, 1998; Leung, Chong & Cheng, 2000; Azzone & Bianchi, 2000; Buchanan-Oliver *et al.* 2000; Knight *et al.,* 2005; Kefos & Riedl, 2005). In contrast, benefit at the individual level perspective denotes the effect of intranet on individual performances such as individual productivity, individual efficiency, and individual effectiveness (Lai & Mahapatra, 1998; Kjernald, 2002; Weber, 2002; Kefos & Riedl, 2005; Daniel & Ward, 2005; Deltour, 2005).

Previous studies addressing intranet effectiveness either at the firm level or individual level perspectives were very much exploratory. Thus, interviews and participant observations was mainly employed in the data gathering techniques Due to that nature of studies, reliable instruments which can be readily used for measuring intranet effectiveness was rarely found. Hence, in an attempt to provide a sound and reliable instrument for measuring intranet effectiveness, Murgolo-Poore *et al.* (2002) developed an intranet pen and pencil checklist that measures effectiveness from three dimensions i.e. operation, culture and facilitation. The operations dimensions assess the extent to which the organization's intranet impacts the way in which the organization operates. The culture dimensions assess the extent to which the organization's intranet impacts the organizational culture. The facilitation dimensions assess the extent to which the organization's intranet facilitates collaboration and cooperation among organizational members. All the 15-items measures recorded an alpha value above 0.90 suggesting that the instrument is highly reliable. The intranet pen and pencil checklist has shown consistent outcome in terms of its reliability in different intranet studies (Weber, 2002; Murgolo-Poore *et al.,* 2003).

Considering that the developer of IS success model (Delone & Mclean, 1992) did not provide the measures or instruments for gauging all the dimensions, its proponents cautioned that only validated measures should be used when using the model. To this effect, the researcher felt that the instrument developed by Murgolo-Poore *et al.* (2002) is most appropriate. Based on its scope and focus, the researcher argues that all the items measuring intranet effectiveness are suitable for organizational impact dimension of IS effectiveness model (Delone & Mclean, 1992), workgroup impact dimension of the comprehensive IS effectiveness model (Myers, Kappelman & Prybutok, 1998) as well as net benefits dimension of updated IS effectiveness model (Delone & Mclean, 2003). More precisely, the culture and facilitation dimension measures workgroup impact dimension while the operation dimension measures the organizational impact dimension.

2.2 IT Infrastructure flexibility

The importance of organizational IT infrastructure capability is increasingly recognized as critical to organizational survival and competitiveness (Broadbent *et al*. 1996; Chung *et al*. 2003). According to Xia & King (2004), IT infrastructure is generally considered to be the foundation of shared IT capabilities that enable the development of IT applications and the support of business processes. They defined IT infrastructure as a set of IT resources and organizational capabilities that are shared across the organization and that provide the foundation on which IT applications are developed and business processes are supported. IT infrastructure capabilities are usually provided by the organizational IT/IS functions (department) but can also encompass public or outsourced facilities used by the organizations (Weill & Broadbent, 1994; PE International, 1995). The prime reason for developing IT infrastructure capabilities is to support the commonality between different application or uses, facilitating information sharing across organization and cross-functional integration (Darnton & Giacolette, 1992)

With regard to flexibility, the term has been defined by most of the literatures, including IS, organization theory, strategic management, and operations management as the capability to respond to environmental changes (Lee & Xia, 2003). Byrd & Turner (2000) defined IT infrastructure flexibility as the organizational capability to support a variety of information technologies and information services. Past studies addressing IT infrastructure flexibility characterized flexibility into four dimensions namely compatibility, connectivity, modularity and flexible IT personnel (Byrd & Turner, 2000; Tallon & Kreamer, 2003; Chung *et al.,* 2003; Ness, 2005; Chung *et al.,* 2005).

Compatibility denotes the ability to share any type of information across any technology component. Connectivity refers to the ability of any technology to attach to any of the other technology components. It also means that every person, every functional area, and every application in the organizations are linked to one another. Modularity signifies that software applications can be more manageable when routines are processed in separate modules. Modularity also provides a firm the ability to quickly build or modify software applications in order to easily support changes in product development. Flexible IT personnel refer to IT workers working cooperatively in cross functional teams embracing different kinds of technologies. Byrd & Turner (2000) noted that IT personnel flexibility should be well-versed in the combination of technical competencies, boundary competencies and functional competencies. Technical competencies denote a set of measures of technical capabilities such as programming, understanding software development process and knowledge of operating systems. Boundary competencies relates to the importance of IT personnel having skills and knowledge to assume roles outside their area of training or original competencies which include project management and business process support. Functional competencies is concerned with the ability of the IT personnel to understand the business processes they are to support and apply the appropriate technical solution to a given business problem.

Based on the items measuring the four dimensions of the IT infrastructure flexibility developed by Byrd & Turner (2000), studies by Chung *et al.,* (2003); Ness, (2005); Chung *et al.* (2005) have found that IT infrastructure flexibility are significantly correlated with IT/IS effectiveness and the extent of IT implementation (i.e. transaction processing systems, management information systems, decision support systems, data warehouse, network management etc). Other studies by Saaksjarvi (2000); Tallon & Kreamer (2005) also indicated that IT infrastructure flexibility are critical in determining IS/IT effectiveness or business performance. In the context of intranet study, Eder & Igbaria (2001) also confirmed that IT infrastructure flexibility were influential in predicting intranet infusion i.e. the process of embedding an intranet application deeply and comprehensively within an individual's or an organization's work systems (Cooper & Zmud 1990).

It has been argued that, in ensuring the effectiveness of the intranet, intranet management activities must be properly in place (Schmmid *et al.* 1999; Terplan, 2000; Masrek *et al.*, 2007). Schmmid *et al.* (1999) elaborates that intranet management comprises of highly heterogeneous activities including content generations and updates, user accounts management, hardware and software maintenance, and many more. On the other hand, Terplan (2000) advocates that in managing intranets, those critical success factors include (i) management processes that may involved fault, configuration, performance, security and accounting management, (ii) management tools that will be utilized for supporting management process and are usually assigned to human resources, and (iii) human resources of the

management team that would embrace their skills and network management experiences.

Based on the arguments by Terplan (2000) and Schmmid *et al.* (1999), it is apparent that intranet management activities are related with the four dimensions of IT infrastructure flexibility. A close scrutiny on items measuring the four dimensions also suggests that these items revolved around intranet management activities. For instance among the items used for measuring compatibility were "*our firm has extensive electronic links and connections throughout the firm*" and "*end users in our organizations are electronically linked with most other end users*". The two items simply imply that the compatibility requirement of IT infrastructure flexibility is that organizations should provide adequate technological infrastructure such as intranet that would enable everyone to be connected. Among items for measuring connectivity include "*our bandwidth capabilities provide access to large variety of data including test, voice and graphical*" and "*our firm has very flexible links in its IT links and connections*". These items clearly stressed the importance of having adequate bandwidth capabilities and flexible IT connectivity such as intranet because that would facilitate users in their data access or retrieval. Likewise, items for measuring modularity and flexible IT personnel relates to the importance of having reusable software modules and competence and flexible IT personnel as that would ensure that new applications can be easily and quickly added onto the intranet, developed by skill IT personnel who are responsive to users needs and flexible enough to be working across diverse business functions. Based on the aforementioned discussion, the researcher also argues that IT infrastructure flexibility should also have significant effect on intranet effectiveness. To this effect, the following hypotheses are formulated:

- *H1: Compatibility of IT infrastructure will be significantly related to intranet effectiveness*
- *H2: Connectivity of IT infrastructure will be significantly related to intranet effectiveness*
- *H3: Modularity of IT infrastructure will be significantly related to intranet effectiveness*
- *H4: Flexibility of IT personnel will be significantly related to intranet effectiveness*

3. Research Methodology

Public organizations consisting both state and federal government agencies were selected as the population for the study. The public sector was chosen because it has long been a leader in the development and use of information systems application. According to Hussein (2004), the public sector should become the next center of empirical research because it is the largest consumer of information technology and the biggest information based organization. A sample frame for the study was drawn from the myGovernment, the Malaysia's government official portal (http://www.gov.my). The portal provides a comprehensive listing and directories of all public agencies both at the state and federal level. By exploring the agencies' websites, the researcher could identify those that have implemented intranet or portal. Based on this exercise, a sampling frame was prepared. Purposeful sampling was adopted because the study would investigate those agencies or department that have implemented intranet and have IT departments. Data was collected using a survey research design employing cross-sectional approach. Self-administered paper-based and electronic questionnaires were posted and e-mailed to 325 agencies, departments, division, statutory bodies both at the federal and state government. As the study adopts organization as the unit of analysis, the questionnaires were addressed to key-informant holding the post of either IT manager, IS executives or senior programmer. To further boost the number of responses, a follow-up e-mail and phone calls were made two weeks after the questionnaires were sent out. A total of 89 questionnaires were returned but only 71 were found usable. Some of the unusable questionnaires were categorized based on the note written by the respondents indicating that there is no IS department in their organization. Others were simply incomplete.

The questionnaire that was used in the study consists of 34 close and open-ended questions divided into four sections preceded with the cover letter explaining the purpose of the questionnaire and the definition of intranet / portal. The first section captures demographic information such as number of years using the intranet / portal, number of years of IS department existence, total number of employees working in IS department and total number of employees working in the organizations. The second section captures information on IT infrastructure flexibility. The third section captures information on the three dimensions of the intranet effectiveness. The last section is an open ended question asking respondents to add additional any comments regarding their IT infrastructure capabilities and intranet effectiveness. Realizing that Malay Language is the main and formal language for any government correspondence in Malaysia, the questionnaire is therefore prepared in that language. Other than questions on demographics information, all other questions were using perceptual measures with a corresponding five point Likert scale ranging from 1 = strongly disagree and 5 = strongly disagree. As noted by Torkzadeh *et al.* (2005), perceptual measures are acceptable measures and extensively used in IS studies. Fifteen items adapted from Chung *et al.* (2005) and Byrd & Turner (2000) were used to measure IT infrastructure flexibility. Thirteen items adapted from Murgolo-Poore *et al.* (2002) were used to measure intranet effectiveness.

4. Findings

Based on the 71 usable responses, data were analyzed using SPSS version 14.0. Non-response bias was checked based

on two groups i.e. early responders vs. late responders using ANOVA and the results yielded that there was no significant difference between them. Subsequently, factor analysis was executed on the four dimensions of IT infrastructure flexibility i.e. compatibility, connectivity, modularity and flexible IT personnel and the three dimensions of the portal effectiveness i.e. operation, culture and facilitation. In interpreting factors to determine which factor loadings are worth considering, this study adopted loadings of 0.65. All the measures were entered into principle axis factoring with Varimax rotation. The results of the factor analysis revealed that all the five items measuring IT personnel cleanly loaded onto Factor 1, all the three items measuring modularity cleanly loaded onto Factor 3, all the three items measuring connectivity plus two items measuring compatibility loaded onto Factor 2. Following this results, the four antecedent factors are reduced to only three and named as flexible IT personnel, modularity and connectivity. Two items from the compatibility measures had to be dropped as they did not meet the cut-off point. As for the intranet effectiveness dimensions, the results indicated that all the five items measuring facilitation dimension cleanly loaded into Factor 1, all the four items measuring cultural dimension cleanly loaded into Factor 2, and all the four items measuring operation dimension cleanly loaded into Factor 3. Thus, the original three dimensions of the intranet effectiveness were retained. Accordingly, reliability analyses were performed on the intranet effectiveness measures and all the three antecedents' factors measures. Result of this procedure is shown at Table 1.

4.1 Demographic

Table 2 presents the profile of the responding organizations. Majority of the respondents or 53.5 % indicated that their organizations had implemented intranet between 3 and 6 years. 16.9 % of the respondents indicated that intranet had been used between 7 and 10 years. The high percentage of organizations implementing intranet between 3 and 10 years could be attributed by the fact that Malaysia has recovered from the economic downturn experienced in 1997 to 1999. Hence, the spurring economic for the last 7 to 8 years has enabled the government of Malaysia to allocate more fund for ICT deployment expenditure. 11.3 % of the respondents indicated that they had used intranet either more than 12 years or between 11 and 12 years. A post-examination on the questionnaires revealed that these figures came from huge organizations such as ministries or universities at the federal government.

With regard to the age of their IT departments, majority or 52.1% of the respondents answered that IT departments had existed either more than 12 years or between 11 and 12 years. Driven by the growing numbers of public employees and motivated by the realization of the importance of IT functions in realizing paperless office, a relatively high percentage of respondents indicating that their IT departments had existed between 3 and 10 years could be justified. The statistics of the responding organizations also suggest that more than 85% indicated that the number of staffs working in the IT department is between 10 and 40 people. Only 4.2% responded that the number of staffs is more than 70 people. Questions on the number of staffs working in the entire organizations revealed that more than 80% indicated that there are more than 130 people. This huge number implies that intranet utilization is more appropriate and practical in situation where there is large number of users.

4.2 Descriptive statistics

As discussed in the preceding section, the study was carried out with the purpose of investigating the perceived level of IT infrastructure flexibility and intranet effectiveness in participating organizations. To accomplish this research objective, a descriptive statistics for each item measuring all factors relating to IT infrastructure flexibility and intranet effectiveness is prepared. As shown in Table 3, the mean score for each item measuring connectivity and IT personnel is all above 3, implying that respondents generally agree that IT infrastructure in their agencies are flexible in terms of connectivity and IT personnel. However, items measuring modularity scored mean values less than 3 and hence suggesting that respondents generally perceived that IT infrastructure in terms of modularity aspect in government agencies is less flexible. In terms of perceived intranet effectiveness, the mean value for all items of the three dimensions measuring intranet effectiveness is well above 3 and hence signifies that respondents were generally agreed that the intranet that are being used in their agencies are effective in terms of enhancing business operation, promoting the desired organizational culture and facilitating collaboration among organizational members (Table 4). This finding is consistent with that of Lai & Mahapatra (1998), Weber (2002), Murgolo-Poore *et al.* (2003) and Knight *et al.,* (2005).

4.3 Relationship between research variables

As mentioned in the preceding section, this study seeks to investigate the effect of IT infrastructure flexibility on intranet effectiveness. Based on the correlation and regression analyses result shown at Table 5, it can be concluded that H2, H3, and H4 are fully supported. Both connectivity and IT personnel demonstrated high correlation value with intranet effectiveness with each measuring at 0.739 and 0.731 respectively. Correlation between modularity and intranet effectiveness recorded an r-value of 0.476 which can still be considered as strong. These findings denote to some extent that the degree of connectivity, modularity and IT personnel would relate to higher degree of intranet effectiveness. These findings are consistent with Eder & Igbaria (2001), Chung *et al.* (2003) and Chung *et al.* (2005) and imply that a high degree of IT infrastructure flexibility would relate to a higher degree of intranet effectiveness.

To further investigate the quantitative estimates of the hypothesized linkages, a path analysis was executed. Path analysis is an extension of the multiple regression technique that examines the pattern of relationship between three or more variables (Bryman & Cramer, 2001). Path analysis also confirms the model produced by regression analysis (Pedhazur, 1997). AMOS version 5.0 was used to execute the path analysis. The results as shown in Figure 2 indicated that amongst the three antecedent variables, modularity was not found to be strong predictor of intranet effectiveness.

5. Discussion and conclusion

The central focus of this study was to investigate the relationship between IT infrastructure flexibility and intranet effectiveness. In the process, instruments developed by Murgolo-Poore *et al.* (2002) was used to measure intranet effectiveness while the instrument from Chung *et al.* (2005) but originally developed by Byrd & Turner (2000) was adopted to measure IT infrastructure flexibility. Upon doing factor analysis, the items grouping of the intranet effectiveness measures turned out to be consistent with the conceptualized dimensions. This finding further supports previous studies by Weber (2002) and Murgolo-Poore *et al.,* (2003) and hence suggests that the instrument is highly reliable. However, when similar analysis was applied to the IT infrastructure flexibility instrument, the results emerged to be different from the initial conceptualized dimensions. More specifically, several items measuring compatibility turned out to be insignificant while the remaining items had loaded onto connectivity dimension. This finding is not considered uncommon as the original instrument developed by Byrd & Turner (2000) had also yielded almost similar results and that they have used the term integration to represent those items from both connectivity and compatibility dimensions.

Having confirmed with the acceptability level of the reliability of the research instrument, further analysis involving correlation and liner regression were employed with the purpose of testing the formulated hypotheses. Evidently, the results turned out to be consistent with the researcher's expectations and that H2, H3 and H4 were supported. Conversely three dimensions of IT infrastructure flexibility i.e. connectivity, modularity and flexible IT personnel are significantly related to intranet effectiveness. Subsequent analysis further unveiled two most significant predictors of intranet effectiveness were connectivity and flexible IT personnel. One plausible explanation as to why modularity was not found to be strong predictor could be that most IS projects in Malaysian government agencies are not in-house developed but outsourced to third party software developer or vendors. The propriety nature of software or application systems brought by these different vendors would definitely reduced modularity. Nevertheless, as opposed to modularity, both connectivity and flexible IT personnel have shown their predictive power in explaining intranet effectiveness. Apparently, in accomplishing connectivity, organizational members or functional units could exploit the use of organizational intranets. The more is the intranet being used, the more it would be perceived as being effective. Likewise, as the intranet is being continuously used, the on-going support and maintenance by the IS/IT function is very critical. An effective team comprising of flexible IT personnel would certainly ensure that the intranet would not fail.

In essence, the study has contributed to the body of knowledge in three perspectives. First, it has developed empirical based framework linking IT infrastructure flexibility and intranet effectiveness. The framework could be use by other prospective researchers to study divers IS/IT implementation settings. Secondly, from the methodological standpoint, the study has successful validated the instruments used by previous researcher and applied in intranet implementation settings. Thirdly, from the pragmatic standpoint, the instrument used in the study can be utilized as a checklist by intranet practitioners to evaluate their IT infrastructure flexibility as well as their intranet effectiveness. Also, as this study has shown the effect of IT infrastructure flexibility on intranet effectiveness, it does send a strong message to IS planners of the importance of giving serious attention on IT infrastructure flexibility issue when devising IS planning.

While this study has successfully accomplished its objectives, it bears several limitations. The perceptual self-report measures instead of objectives measures adopted in this study would contribute to biasness. Furthermore, this study adopted a cross-sectional design hence data was captured only at one point in time. Future research should consider conducting similar study employing experimental design study or even longitudinal study to capture data of a given time frame is also seen plausible. Other possible approach could be mixing the qualitative and quantitative design involving in-depth interview with users and observation in a natural intranet usage setting.

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Table 1. Reliability analysis of research variables

Variables	No. of Items	Reliability (*Cronbach Alpha*)
Connectivity	5	0.89
Modularity	3	0.96
IT Personnel	5	0.93
Overall Intranet Effectiveness Measure	13	0.88

Table 2. Profile of respondents

Characteristics	Items	Frequency	Percentage
Age of Intranet Usage	< 1 or 1 – 2	13	18.3
	3 – 6	38	53.5
	7 – 10	12	16.9
	11 – 12 or > 12	8	11.3
Age of IT Department	< 1 or 1 – 2	0	0
	3 – 6	16	22.5
	7 – 10	18	25.4
	11 – 12 or > 12	37	52.1
No of staffs in IT Department	< 10 or 10 – 20	32	45.1
	21 – 40	30	42.3
	41 – 60	6	8.5
	61 – 70 or > 70	3	4.2
Total no. of staffs in agencies	< 30 or 30 – 50	2	2.8
	51 – 90	6	8.5
	91 – 130	6	8.5
	130 – 150 or > 150	57	80.3

Table 3. Descriptive statistics of IT infrastructure flexibility

Modularity	Mean	Std. Dev.
Reusable software modules are widely utilized in new systems development in our firm	2.46	1.067
IT personnel utilize object-oriented and other modular tools to create software applications	2.42	1.023
Computer software modules can easily be added to, modified or removed from the existing IT infrastructure with very few problems	2.46	1.119
IT Personnel	**Mean**	**Std. Dev.**
Our IT personnel work well in cross-functional teams addressing business problems	3.70	0.800
Our IT personnel are encouraged to learn new technologies	3.49	0.876
Our IT personnel are able to interpret business problems and develop appropriate technical solutions	3.69	0.748
Our IT personnel have the ability to work cooperatively in a team environment	3.72	0.759
Our IT personnel are in multiple technologies and tools	3.68	0.732

Table 4. Descriptive statistics of intranet effectiveness

Operation	Mean	Std. Dev.
Our intranet has changed the way our firm communicate internally	3.42	0.889
Our intranet is very effective for saving resources, such as times, facilities and money	3.46	0.842
Our intranet has become an integral part of the way we operate	3.54	0.983
Our intranet brings us together and helps us work more effectively	3.72	0.778
Culture	**Mean**	**Std. Dev.**
Our intranet is a solution of bringing people within our organization together	3.90	0.848
Our intranet provides major cultural revolution in our firm in the way people work, think and communicate	3.92	0.824
Our intranet has truly allowed a global community to grow	3.55	1.131
The overall effect of our intranet has been to make our members of our firm better communicator	3.94	0.843
Facilitation	**Mean**	**Std. Dev.**
Our intranet foster collaboration	3.58	0.690
Our intranet allows to effectively implement business strategy	3.58	0.710
Our intranet helps to bring product or services much quicker	3.73	0.774
Our intranet is a way to communicate, design, develop and deliver new product or services	3.63	0.702
Our intranet makes our employee feel like a significant part of the firm	3.61	0.707

Table 5. Correlation and linear regression results

	Dependent Variable: Intranet Effectiveness					Hypotheses Testing
Independent Variable	R^2	F	β / r	t	P value	Outcome
Connectivity	0.547	83.151	0.739**	9.119	0.00	H2: Supported
Modularity	0.227	20.221	0.476**	4.497	0.00	H3: Supported
Flexible IT Personnel	0.535	79.232	0.731**	8.901	0.00	H4: Supported

** *Correlation is significant at 0.01 level (2-tailed)*

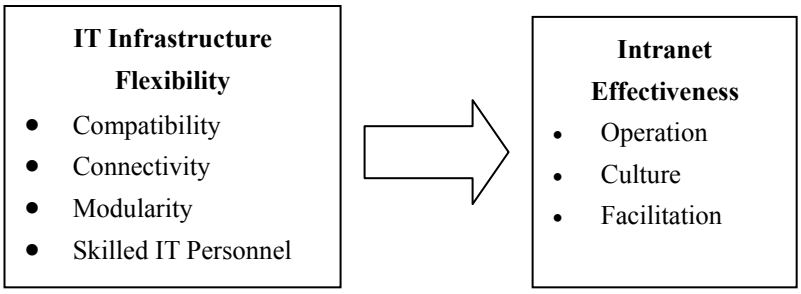

Figure 1. The Research Model

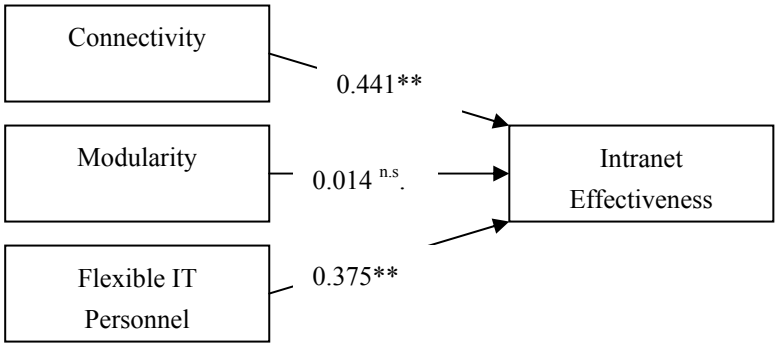

Figure 2. Path analysis of research model

*Legend: ** = significant at 0.001 level, n.s. = non significant*