行政院國家科學委員會專題研究計畫 成果報告

語言評判技術於通用設計產品評價之應用研究
研究成果報告(精簡版)

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 100-2221-E-214-073-
執 行 期 間 ：100 年 08 月 01 日至 101 年 07 月 31 日
執 行 單 位 ：義守大學創意商品設計學系

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報 告 附 件 ：出席國際會議研究心得報告及發表論文

公 開 資 訊 ：本計畫可公開查詢

中 華 民 國 101 年 07 月 23 日

中文摘要： 由於平均壽命增加且現代醫學提高人類因受傷、生病與出生缺陷的存活率，人們逐漸關注通用設計議題。『通用設計』是一項用於發展產品及環境的方法，使其在最大程度範圍內，能被所有人使用。雖然現行通用設計原則可以提供明確的設計指引參考，但由於僅具條列式質化描述屬性，不易以科學量化方式，準確評估產品之通用設計優劣。本研究提出一套模糊語言方法用於評估產品通用設計，本方法利用模糊語言變數結合模糊加權平均法，進行喜好度資訊之聚積運算。為了說明方法之實用性，本研究以簡單的層級結構作決策個案，執行產品選項評估，而個案結果呈現相當可靠度。本研究所提出的模糊語言方法可以有效協助處理具質化屬性之複雜決策評估問題。

中文關鍵詞： 通用設計、模糊語言方法、評估、模糊加權平均法

英文摘要： As life expectancy rises and modern medicine increases the survival rate of those with significant injuries, illnesses, and birth defects, there is a growing interest in universal design. Universal design is an approach of developing products and environments to be usable by all people, to the greatest extent possible. Although a set of acknowledged principles has been developed and commonly used by industry and academic community, it is difficult to quantitatively assess whether a product is indeed a good example of universal design. This study presents a fuzzy linguistic approach for universal design assessment. The proposed approach is based on fuzzy linguistic variables associated with the fuzzy weighted average techniques for aggregating preference information. To illustrate the practicability of the proposed approach, a case study using a simple hierarchy structure to assess product alternatives was conducted. It has shown a credible result. The fuzzy linguistic approach has proven to be useful in dealing with complex assessment problems involved in qualitative attributes.

英文關鍵詞： Universal design； Fuzzy linguistic approach； Assessment； Fuzzy weighted average

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成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

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執行單位：義守大學

中　華　民　國　101　年　7　月　20　日

A linguistic evaluation approach for universal design

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中文摘要

由於平均壽命增加且現代醫學提高人類因受傷、生病與出生缺陷的存活率，人們逐漸關注通用設計議題。『通用設計』是一項用於發展產品及環境的方法，使其在最大程度範圍內，能被所有人使用。雖然現行通用設計原則可以提供明確的設計指引參考，但由於僅具條列式質化描述屬性，不易以科學量化方式，準確評估產品之通用設計優劣。本研究提出一套模糊語言方法用於評估產品通用設計，本方法利用模糊語言變數結合模糊加權平均法，進行喜好度資訊之聚積運算。為了說明方法之實用性，本研究以簡單的層級結構作決策個案，執行產品選項評估，而個案結果呈現相當可靠度。本研究所提出的模糊語言方法可以有效協助處理具質化屬性之複雜決策評估問題。

關鍵字：通用設計、模糊語言方法、評估、模糊加權平均法

Abstract

As life expectancy rises and modern medicine increases the survival rate of those with significant injuries, illnesses, and birth defects, there is a growing interest in universal design. Universal design is an approach of developing products and environments to be usable by all people, to the greatest extent possible. Although a set of acknowledged principles has been developed and commonly used by industry and academic community, it is difficult to quantitatively assess whether a product is indeed a good example of universal design. This study presents a fuzzy linguistic approach for universal design assessment. The proposed approach is based on fuzzy linguistic variables associated with the fuzzy weighted average techniques for aggregating preference information. To illustrate the practicability of the proposed approach, a case study using a simple hierarchy structure to assess product alternatives was conducted. It has shown a credible result. The fuzzy linguistic approach has proven to be useful in dealing with complex assessment problems involved in qualitative attributes.

Keywords: Universal design; Fuzzy linguistic approach; Assessment; Fuzzy weighted average

1. Introduction

With the rapid evolution of an aging society in the developed countries and an increase in the demand of people with disabilities for full recognition of their civil rights, the concept of universal design is currently being applied to a variety of fields including architecture, landscape, and product design. Many facility managers have recognized the advantages of applying universal design in their workplaces and practice it at any level of application (Saito, 2006). Universal design is an approach to creating everyday environments and products that are usable by all people to the greatest extent possible, regardless of age or ability (Mace, 1985; Ostroff, 2001; Story, 1997), or without the need for adaptation or specialized design (Center for Universal Design, 1997). It emerged from slightly earlier "barrier-free" concepts, the broader accessibility movement, and adaptive and assistive technology and also seeks to blend aesthetics into these core considerations. In practice, it is neither an assistant technology nor a euphemism for accessible design. Rather, universal design involves a fundamental shift in thinking about accessibility away from the practice of removing or overcoming environmental barriers for an individual or a particular group of people to a way of meeting the environmental needs of all users (Bednar, 1977). Universal design is regarded as a goal that puts a high value on both diversity and inclusiveness, maximizing the usability of products and environments (Story, 1998). Recently, researchers have worked on developing ways to incorporate the actual concept of universal design into the design process (Mueller, 2001; Preiser, 2001; Story et al., 2000; 2001). A group of experts in the area of universal design have developed a set of simple principles that allows a systematic assessment of new or existing designs and assists in educating both designers and consumers about the characteristics of more usable products and environments (Beecher & Paquet, 2005; Center for Universal Design, 1997; Story, 1997; 1998). Since then, designers have become familiar with the unifying principles of universal design and have developed many products based on this paradigm (Demirbilek & Demirkann, 2004; Mamee & Sahachaisaeree, 2010). However, the principles of universal design are qualitative in nature. It is difficult to quantitatively assess whether a product is indeed a good example of universal design or not (Kato et al., 2009).

Assessment is a systematic determination of merit, worth, and significance of something using criteria against a set of rules. It involves the human perceptual interpretation with certain uncertainty and imprecision. As such perceptual interpretation usually refers to the non-quantifiable, subjective, and affect-based process, it is difficult to be objectively explored by a conventional research approach, particularly using such qualitative criteria as universal design principles. Recent development on artificial intelligence methods offers a powerful tool to deal with concepts and rules with uncertainty and subjective vagueness, especially in real life situations where absolute precision has little relevance while a robust representation of relative trend is more valuable. Fuzzy set theory was advanced by Zadeh (1965). It launches a scientific revolution based on the premise that the key points in human thinking are not numbers, but linguistic terms (Bellman & Zadeh, 1970). During the past decades, numerous decision-making methods based on fuzzy set theory have been proposed and used (Baas & Kwakernaak, 1997; Kuo et al., 2006; Yang et al., 2008; Zimmermann, 1987). Van Laarhoven and Pedrycz (1983) first evolved Saaty's AHP into the fuzzy AHP to solve vague problems that occur during the analysis of criteria and judgment process. Many systematic approaches integrated the concepts of fuzzy set theory into the AHP technique to solve imprecise hierarchical problems in the real-world decision making (Dağdeviren & Yüksel, 2008; Sun, 2010; Torfi et al., 2010). Although the fuzzy AHP can deal with the uncertain comparisons using fuzzy scales and has largely been used in related research fields (Dağdeviren & Yüksel, 2008; Erensal et al., 2006; Lin, 2010), it is difficult to preserve a consistent pairwise comparison to ensure the order of the preference intensities in the resultant priorities (Çakır, 2008; Wang & Chen, 2008).

In modeling decision processes, preference relations are the most common representation of information used for solving decision-making problems. Generally, these preference relations can be categorized into multiplicative preference relations (Fan et al. 2006; Herrera et al., 2001), fuzzy preference relations (Berredo et al., 2005; Wang & Fan, 2007), and linguistic preference relations (Herrera & Herrera-Viedma, 2000; Xu, 2005). As mentioned above, the principles of universal design are characterized as qualitative paradigm. The decision situation in which the alternatives cannot be assessed precisely in a quantitative manner but may be in a qualitative one, thus the use of linguistic assessments is very appropriate (Delgado et al., 1992; Herrera et al., 1998). The fuzzy linguistic approach is an approximate technique which represents qualitative aspects as linguistic values by means of linguistic variables (Zadeh, 1975; 1976). In this paper, a novel linguistic assessment approach is presented, which can be used to assist decision makers in assessing product design in terms of the universal design perspective. The remainder of this paper is organized as follows. Section 2 introduces the proposed linguistic assessment approach. Section 3 presents a case study to illustrate the practicability of the proposed approach. Finally, concluding remarks are drawn in Section 4.

2. Outline of the fuzzy linguistic assessment approach

Universal design refers to a broad-spectrum planning idea that can permeate more business practices in more companies to produce buildings, products and environments that are inherently accessible to both the able-bodied and the physically disabled users (Tobias, 1997). The intent of universal design is to simplify life for everyone by making products, communications, and the built environment more usable by as many people as possible at little or no extra cost. Based on the universal design principles and fuzzy linguistic techniques, the implementation methods are illustrated step by step as follows:

Step 1. Select a set of products as decision alternatives for the evaluation.

Step 2. Construct a hierarchy based on the universal design principles.

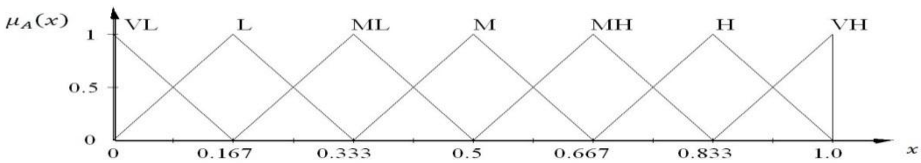
An AHP hierarchy is a structured means of modeling the decision problem. Based on the universal design principles, a simple hierarchy is constructed. The goal is to evaluate the universal design of the selected product alternatives (Level 1). Under the overall goal, the second level represents the criteria based on the seven items of the universal design principles (see Table 3). The product alternatives are linked to the third level.

Step 3. Conduct a universal usability testing.

Universal usability refers to the design of products and services that are usable for every citizen, recognizing the diversity of user population and user needs. Usability testing focuses on measuring a human-made product’s capacity to meet its intended purpose. The purpose of the universal usability testing is to measure how well test subjects respond in the criteria of the seven universal design principles. The test subjects are divided into expert and user groups. Both groups of subjects are required to evaluate the selected product alternatives according to the universal usability testing results. A post-test questionnaire is then used to gather feedback on the products being tested. The evaluation grades are 7-point Likert scales, ranging from “strongly disagree” to “strongly agree”. Each Likert scale corresponds to a linguistic variable with a crisp number as given in Table 1.

Table 1. Definitions of linguistic variables based on triangular membership functions

Label	Semantic element / Likert scale/Level of agreement	Fuzzy number $\propto \in [0.1]$	Crisp number $\propto = 1$	Latent number $\propto = 0.5$
VL	Very low importance/satisfaction / Strongly disagree	[0, 0.167]	0	[0, 0.083)
L	Low importance/satisfaction / Disagree	[0, 0.333]	0.167	[0.083, 0.250)
ML	Medium low importance/satisfaction / Somewhat disagree	[0.167, 0.5]	0.333	[0.250, 0.416)
M	Medium importance/satisfaction / Neither agree nor disagree	[0.333, 0.667]	0.5	[0.416, 0.583)
MH	Medium high importance/satisfaction / Somewhat agree	[0.5, 0.833]	0.667	[0.583, 0.750)
H	High importance/satisfaction / Agree	[0.667, 1]	0.833	[0.750, 0.916)
VH	Very high importance/satisfaction / Strongly agree	[0.833, 1]	1	[0.916, 1]



Triangular membership functions of the linguistic sets

Step 4. Determine a set of linguistic weight vectors for the criteria.

The importance (weights) of the criteria is a critical factor in a decision-making process. It must be more objectively and equitably determined. Expert review is a general method of usability testing that relies on bringing experts in with their knowledge and experience in the professional field to evaluate the usability of a product. According to the testing results, experts evaluate the product alternatives through the Likert-type questionnaire. Substituting these scoring data into SPSS software to perform the Pearson distance correlation analysis in pairs, we can derive a proximity matrix that is regarded as a covariance matrix. Taking advantage of the eigenvalue algorithms, a set of values corresponding to the criteria is derived. These values are used as the weightings determined through the expert group’s judgments. They are latent numbers and must be converted into linguistic variables for the following aggregation operation.

According to the interval of converting scales given in Table 1, we can determine a set of linguistic weight vectors w_j.

Step 5. Derive a set of linguistic preference vectors for the product alternatives.

The concept of universal design focuses on how a product is usable by all people to the greatest extent possible. It is very important to take account of users' participation in the assessment when conducting a universal design study (Sanford et al, 1998). In this step the priorities for the product alternatives with respect to each criterion are evaluated by users through the usability testing and the post-test questionnaire. They judge the alternatives according to their actual experience and perception of using the products. The quantitative values are also latent numbers obtained through averaging the user group's preference judgments. After converting these quantitative parameters into linguistic variables, a set of linguistic preference vectors, r_j, can be derived.

Step 6. Aggregate the linguistic variables and rank the alternatives.

In the literature, many aggregation operators have been developed to aggregate information (for details, see Xu & Da, 2003). The fuzzy weighted average (FWA) is one of the important operators which can be used in situations where the arguments are inexact numeric variables (Dong & Wong, 1987; Kao & Liu, 2001). It is a combination of extended algebraic operations to be used in the assessment of alternatives when their corresponding importance (weights) and ratings of criteria are represented by fuzzy numbers. The operation of FWA can be formularized as follows (Vanegas & Labib, 2001):

$$D = \frac{\sum_{j=1}^{m} w_j \cdot r_j}{\sum_{j=1}^{m} w_j} \tag{1}$$

where

D represents the overall desirability of an evaluated alternative;

r_j represents the rating of the j^{th} criterion;

w_j represents the importance (weight) of the j^{th} criterion.

The variables D, r_j, and w_j are fuzzy numbers. It is quite a problem how to perform arithmetic operations with such fuzzy numbers when dealing with the aggregation of linguistic information (Bonissone, 1982). Based on the extension principle (Zadeh, 1965; 1975; 1976), the fuzzy arithmetic operations have been defined to manipulate fuzzy numbers. Besides, according to Klir and Yuan (1995), any fuzzy number can be completely defined by its family of α-cuts, and the extended algebraic operations can be defined based on arithmetic on intervals and assuming that fuzzy numbers are represented by continuous membership functions. The fuzzy set obtained by the four arithmetic operations on fuzzy numbers *A* and *B* on $\mathcal{R}$, is defined by its α-cuts. For the purpose of algebraic operations with fuzzy numbers, an arithmetic operation on fuzzy numbers *A* and *B* can be reduced to operations on intervals $A_\alpha = [a, b]$ and $B_\alpha = [c, d]$.

Through the arithmetic operations, the family of α-cuts defined as a resultant membership function of the evaluated alternative can be presented in a membership function curve, and it also can be classified as a fuzzy number. In order to obtain a quantitative value of the resultant membership function, the center-of-gravity method known as "defuzzification" is used in this study. The formula of the center-of-gravity method can be expressed as below:

$$\bar{x} = \frac{\int_a^b m(x)\cdot x dx}{\int_a^b m(x) dx} \tag{2}$$

where

$m(x)$ represents the degree of membership of the (crisp) variable x;

a and b are respectively the lower and upper limits of the support of the fuzzy number.

3. Case study

This section conducts an empirical study to illustrate the implementation of the proposed approach. The aim of this experiment is to assess the most desirable alternatives from a set of selected products in terms of the universal design perspective. The experiment consisted of two parts: (1) a pilot test to determine the importance (weights) of the criteria, and (2) the universal design assessment for the selected product alternatives.

3.1. Participants

The empirical study involved 3 experts in the pilot test and 20 users in the universal design assessment. The experts were qualified with at least 5 years of personal work experience and are familiar with the unifying principles of universal design. A total of 20 subjects including 18 able-bodied and 2 physically disabled (1 hearing-impaired and 1 right-forearm-impaired) users participated in the universal design assessment. These subjects consisted of 11 females and 9 males, ranging in age between 12 and 68 years (Mean=26.7, S.D.=12.53).

3.2. Product alternatives

Six handy staplers were selected as product alternatives to conduct the universal design assessment. The specifications of the product alternatives are listed in Table 2.

Table 2. List of product alternatives for the universal design assessment

Alternative 1	Alternative 2	Alternative 3
		
KW-triO 5109T	MAX HD-10F	Hippo stapler CG-ST-108
Size: 97mm(L)×23mm(W) ×41mm(H); Weight: 55g	Size: 95mm(L) ×25mm(W) ×50mm(H); Weight: 105g	Size: 115mm(L) ×60mm(W) ×45mm(H); Weight: 72g
Alternative 4	Alternative 5	Alternative 6
		
SDI NO.1113C	SIMBALION HS-10	PLUS ST-010A
Size: 80mm(L) ×30mm(W) ×55mm(H); Weight: 90g	Size: 98mm(L) ×20mm(W) ×46mm(H); Weight: 62g	Size: 75mm(L) ×25mm(W) ×47mm(H); Weight: 75g

3.3. Usability tasks

Setting up a usability test involves carefully creating a scenario or realistic situation. The usability tests required participants (both the experts and the users) to perform defined tasks with each of the selected products. Before the usability test began, the experimenter provided a summary of the procedure. Participants used each of the selected staplers to staple five sheets of paper (A4 size) for at least ten times. This task also asked them to add staples inside the stapler before proceeding and draw out the rest after completing the stapling. After having finished the testing task, a questionnaire was provided to the participants immediately (see Table 3). This questionnaire was constructed according to the goal of the usability testing and the proprieties of the selected products corresponding to the universal design principles.

Table 3. Likert-type questions corresponding to the criteria

	Criterion	Question
1	Equitable use	This stapler is useful and attractive to me.
2	Flexibility in use	This stapler accommodates my preferences and I can use this product in whatever ways are efficient and effective for me.
3	Simple and intuitive use	I can easily and intuitively identify the features of this stapler in order to use it.
4	Perceptible information	I can clearly use the stapler and replenish the staples, regardless of ambient conditions.
5	Tolerance for error	If I make a mistake when using this stapler, it will not injure me.
6	Low physical effort	I can use this stapler with less effort and without causing hand pain from repetitive stapling.
7	Size and space for approach and use	This stapler fits my hand size and I can use it in any posture.

3.4. The pilot test

The purpose of the pilot test was to determine the importance (weights) of the criteria through expert evaluation. The three experts directly evaluated the selected product alternatives according to the usability testing results. The means of the expert group's quantitative judgments corresponding to each criterion were classified as the following matrix.

$$X = \begin{bmatrix} 0.444 & 0.444 & 0.611 & 0.611 & 0.444 & 0.556 & 0.722 \\ 0.778 & 0.833 & 0.944 & 0.944 & 0.889 & 0.944 & 0.778 \\ 0.278 & 0.167 & 0.333 & 0.111 & 0.222 & 0.111 & 0.278 \\ 0.833 & 0.833 & 0.889 & 0.944 & 0.889 & 0.922 & 0.944 \\ 0.278 & 0.389 & 0.611 & 0.389 & 0.389 & 0.389 & 0.667 \\ 0.722 & 0.722 & 0.833 & 0.833 & 0.833 & 0.778 & 0.944 \end{bmatrix} \tag{3}$$

Substituting these scoring data into SPSS software to perform the Pearson distance correlation operation, we can obtain a proximity matrix as below:

$$R = \begin{bmatrix} 1.000 & 0.828 & 0.569 & 0.749 & 0.920 & 0.762 & 0.000 \\ 0.828 & 1.000 & 0.954 & 0.932 & 0.974 & 0.971 & 0.411 \\ 0.569 & 0.954 & 1.000 & 0.887 & 0.861 & 0.933 & 0.488 \\ 0.749 & 0.932 & 0.887 & 1.000 & 0.846 & 1.000 & 0.554 \\ 0.902 & 0.974 & 0.861 & 0.846 & 1.000 & 0.877 & 0.309 \\ 0.762 & 0.971 & 0.933 & 1.000 & 0.877 & 1.000 & 0.457 \\ 0.000 & 0.411 & 0.488 & 0.554 & 0.309 & 0.457 & 1.000 \end{bmatrix} \tag{4}$$

Taking advantage of the eigenvalue algorithms, we can derive the following set of eigenvalues and their corresponding eigenvectors.

$$\lambda_{Stapler} = \{5.554, 1.077, 0.268, 0.16, -0.04, -0.004, -0.016\} \Rightarrow \lambda_{max} = 5.554 \quad (5)$$

By calculating the absolute values of the eigenvectors corresponding to the maximum eigenvalue, we determined a set of the priorities of the principal diagonal elements. The obtained values were then converted into linguistic weight variables as listed in Table 4.

Table 4. Linguistic weight variables (w_j) for the criteria of the universal design assessment

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7
Weight	0.345	0.423	0.395	0.411	0.404	0.417	0.2
Order	*6*	*1*	*5*	*3*	*4*	*2*	*7*
w_j	ML	M	ML	ML	ML	M	L

3.5. The universal design assessment for the selected product alternatives

According to the usability testing results, the user group's quantitative judgments with respect to the product alternatives were categorized and converted into linguistic preference variables as listed in Table 5.

Table 5. Linguistic preference variables (r_j) for the product alternatives with respect to each criterion

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7
Alternative 1	M (0.542)	MH (0.583)	MH (0.65)	MH (0.692)	M (0.575)	MH (0.633)	MH (0.683)
Alternative 2	MH (0.7)	MH (0.742)	H (0.758)	H (0.8)	MH (0.683)	MH (0.7)	MH (0.7)
Alternative 3	ML (0.408)	L (0.233)	ML (0.375)	L (0.242)	M (0.425)	ML (0.325)	ML (0.267)
Alternative 4	H (0.775)	H (0.758)	H (0.783)	H (0.783)	MH (0.708)	MH (0.7)	MH (0.608)
Alternative 5	M (0.492)	MH (0.583)	MH (0.658)	MH (0.617)	M (0.525)	M (0.483)	MH (0.633)
Alternative 6	MH (0.7)	MH (0.642)	H (0.808)	MH (0.717)	MH (0.675)	MH (0.7)	MH (0.717)

Based on the results of Table 4 and Table 5, substituting these linguistic variables into Formulas (1) to perform the FWA operation, we derived a set of membership functions, which are presented in membership function curves as shown in Figure 1.

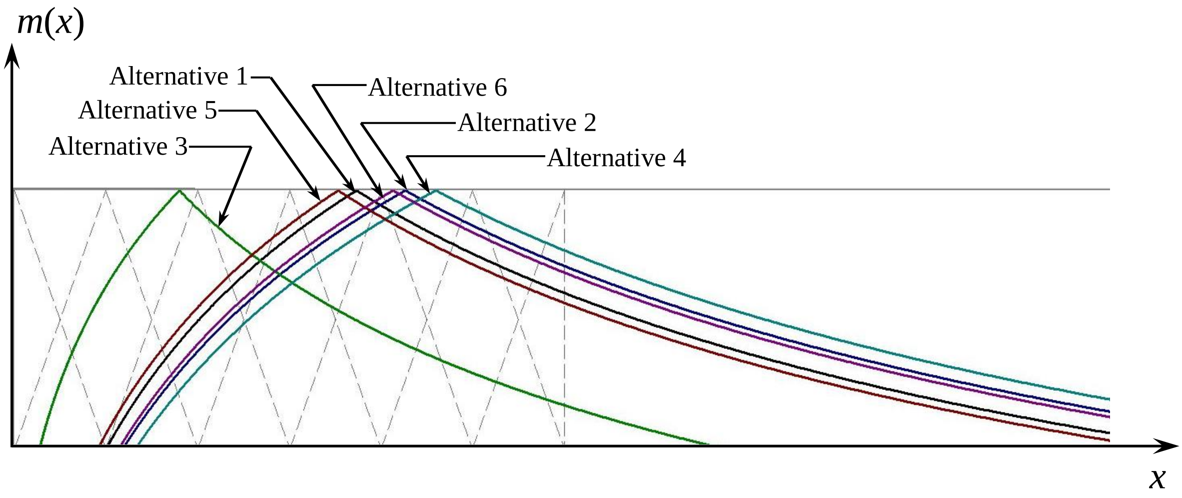


Figure 1. Resultant membership function curves

Further defuzzificating the fuzzy numbers by using the center-of-gravity method, we obtained a set of quantitative values as well as ranked the product alternatives. The final results of the universal design assessment are listed in Table 6.

Table 6. Final results of the universal design assessment

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Quantitative values	0.885	0.999	0.479	1.068	0.845	0.971
Rank	4	2	6	1	5	3

According to the assessment results, we found that the best example is Alternative 4 while the worst is Alternative 3. Alternative 3 has a cute hippo-like appearance but lacks for something about the universal usability. Alternative 4 is a flat-clinch stapler that the staples are clinched flat on the back, reducing the risk of staple scratches. In addition, its twin-lever mechanism can cut stapling effort and reduce hand pain from repetitive stapling. Although Alternative 2 (Rank 2) also provides the same functionality, it is bigger and heavier than Alternative 4 so that it is less equitable and flexible for users to grip and use. As a whole, the universal design assessment has shown a credible result.

4. Concluding remarks

This study considers the aggregation operator as linguistic variables, and uses the fuzzy weighted average method to perform preference aggregation. In practice, the proposed approach not only considers both the relative important of the criteria and its achieved performance, but also conveys the influence of the evaluator’s evaluation attitudes. It can flexibly reflect any evaluator’s evaluation attitudes such as open, neutral or rigorous. In conclusion, the proposed approach can make an objective assessment that approaches a real decision making situation. It has the potential to be a useful decision-aiding tool for dealing with complex assessment problems. In addition to universal design, this fuzzy linguistic approach can be used to systematically assess alternatives from criteria relevant to a set of qualitative attributes.

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國科會補助專題研究計畫項下出席國際學術會議心得報告

日期：101 年 7 月 20 日

計畫編號	NSC 100-2221-E-214-073		
計畫名稱	語言評判技術於通用設計產品評價之應用研究		
出國人員姓名	周志榮	服務機構及職稱	義守大學 創意商品設計學系副教授兼主任
會議時間	101 年 7 月 10 日 至 101 年 7 月 12 日	會議地點	Airlangga University, Surabaya, Indonesia
會議名稱	(中文)2012 國際組織創新研討會 (英文) 2012 International Conference of Organizational Innovation		
發表論文題目	(中文)以模糊語言技術進行通用設計評估 (英文) Universal Design Assessment based on Fuzzy Linguistic Techniques		

一、參加會議經過

由國際組織創新協會(International Association of Organizational Innovation, IAOI)主辦之 International Conference of Organizational Innovation 2012 年 7 月 10 日至 7 月 12 日於印尼泗水 Airlangga University 舉行。本次研討會計有來自歐、亞、美、非計 20 國學者，發表一百餘篇研究論文。會中除探討各領域組織創新研究趨勢外，並對創意技術、綠色管理及歐洲生活創新網路等議題，提出廣泛的討論。

本次會議議程三天，2012年7月10日(星期二)大會開幕當天，首先由IAOI主席Dr. Dembowski及Airlangga大學經濟與管理學院院長Dr. Anshori致開幕詞與歡迎詞，接著分別由Dr. Eloiza Aparecida Avila de MATOS (Brasil)、Dr. Davorin Kralj (Slovenia)及Dr. Brendan Galbraith (N. Ireland) 等三位學者，針對” 67 Focus on Different Techniques of Creativity”、”Green Management and Leadership for "Greenovate" Organizational Development”、” Emerging Innovation Intermediaries And Methods: The European Network Of Living Labs”等主題發表專題演講。下午開始則於各研討室進行30場次的分組發表。本人投稿論文” Universal Design Assessment based on Fuzzy Linguistic Techniques” 安排於2012年7月10日 13:30～14:50 ROOM 202發表，由Dr. Frederick Dembowski擔任Session

Chair。本論文獲2012 Outstanding Paper Award，於7月10日大會歡迎晚宴中，由IAOI 主席頒獎表揚。

二、與會心得

"創意與創新"為國際間熱門的研究主題，而"組織創新"橫跨眾多學術領域，本次參加研討會除發表Universal Design Assessment based on Fuzzy Linguistic Techniques研究論文外，並參加五場次之Parallel paper presentations及擔任一場次Session chair。其中，Innovational Management與Product Design兩主題為個人研究興趣與目前主要研究方向，藉由參加本次研討會，認識各國學者並了解目前國際間有關創意技術及技術創新領域之發展動向與研究成果，對於後續研究方向擬訂，助益良多。

三、活動照片

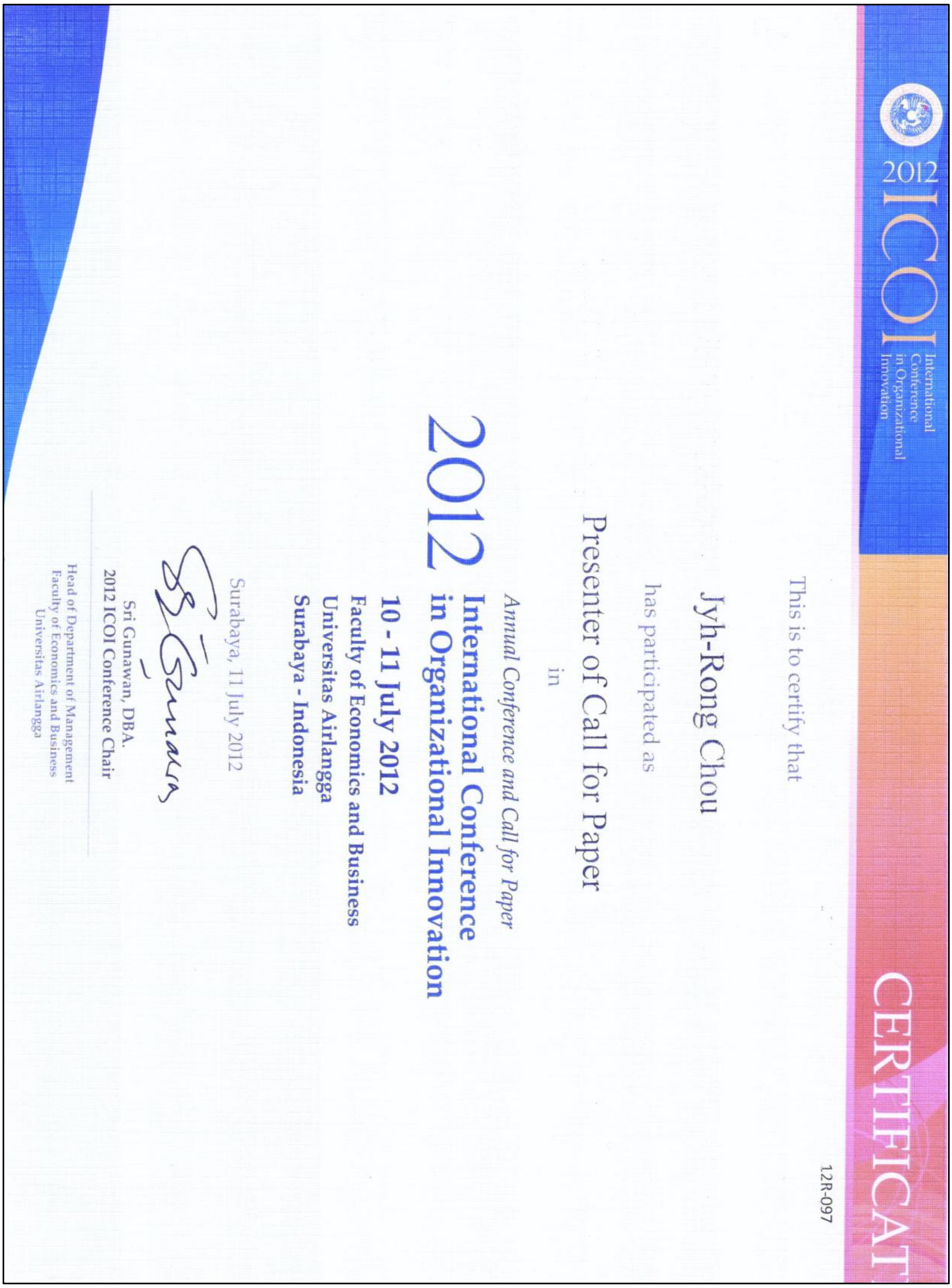
IAOI 主席開幕致詞

Dr. Davorin Kralj 專題演講

團體合照

Outstanding Paper Award 頒獎

四、出席證明


2012 ICOI International Conference in Organizational Innovation
CERTIFICAT
12R-097
This is to certify that
Jyh-Rong Chou
has participated as
Presenter of Call for Paper
in
Annual Conference and Call for Paper
2012 International Conference in Organizational Innovation
10 - 11 July 2012
Faculty of Economics and Business
Universitas Airlangga
Surabaya - Indonesia
Surabaya, 11 July 2012
Sri Gunawan, DBA.
2012 ICOI Conference Chair
Head of Department of Management
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五、發表論文

Universal Design Assessment based on Fuzzy Linguistic Techniques

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Abstract

As life expectancy rises and modern medicine increases the survival rate of those with significant injuries, illnesses, and birth defects, there is a growing interest in universal design. Universal design is an approach of developing products and environments to be usable by all people, to the greatest extent possible. Although a set of acknowledged principles has been developed and commonly used by industry and academic community, it is difficult to quantitativelyassess whether a product is indeed a good example of universal design. This study presents a fuzzy linguistic approach for universal design assessment. The proposed approach is based on fuzzy linguistic variables associated with the fuzzy weighted average techniques for aggregating preference information. To illustrate the practicability of the proposed approach, a case study using a simple hierarchy structure to assess product alternatives was conducted. It has shown a credible result.The fuzzy linguistic approach has proven to be useful in dealing with complex assessment problems involved in qualitative attributes.

Keywords: Universal design; Fuzzy linguistic approach; Assessment; Fuzzy weighted average

1. Introduction

With the rapid evolution of an aging society in the developed countries and an increase in the demand of people with disabilities for full recognition of their civil rights, the concept of universal design is currently being applied to a variety of fields including architecture, landscape, and product design. Many facility managers have recognized the advantages of applying universal design in their workplaces and practice it at any level of application(Saito, 2006). Universal design is an approach to creating everyday environments and products that are usable by all people to the greatest extent possible, regardless of age or ability(Mace, 1985; Ostroff, 2001; Story, 1997), or without the need for adaptation or specialized design(Center for Universal Design, 1997). It emerged from slightly earlier "barrier-free" concepts, the broader accessibility movement, and adaptive and assistive technology and also seeks to blend aesthetics into these core considerations. In practice, it is neither an assistant technology nor a euphemism for accessible design. Rather, universal design involves a fundamental shift in thinking about accessibility away from the practice of removing or overcoming environmental barriers for an individual or a particular group of people to a way of meeting the environmental needs of all users(Bednar, 1977).Universal designis regarded as a goal that puts a high value on both diversity and inclusiveness, maximizing the usability of products and environments(Story, 1998). Recently, researchers have worked on developing ways to incorporate the actual concept of universal design into the design process(Mueller, 2001; Preiser, 2001; Story et al., 2000; 2001). A group of experts in the area of universal design have developed a set of simple principles that allows a systematic assessment of new or existing designs and assists in educating both designers and consumers about the characteristics of more usable products and environments(Beecher &Paquet, 2005; Center for Universal Design, 1997; Story, 1997; 1998).Since then, designers have become familiar with the unifying principles of universal design and have developed many products based on this paradigm(Demirbilek&Demirkann, 2004; Mamee&Sahachaisaeree, 2010). However, the principles of universal design are qualitative in nature. It is difficult to quantitatively assess whether a product is indeed a good example of universal design or not(Kato et al., 2009).

Assessment is asystematic determination of merit, worth, and significance of something using criteria against a set of rules. It involvesthe human perceptual interpretation withcertain uncertainty and imprecision. As such perceptual interpretation usually refers to the non-quantifiable, subjective, and affect-based process, it is difficult to be objectively explored by a conventional research approach, particularly using such qualitative criteria as universal design principles.Recent development on artificial intelligence methods offers a powerful tool to deal with concepts and rules with uncertainty and subjective vagueness, especially in real life situations where absolute precision has little relevance while a robust representation of relative trend is more valuable.Fuzzy set theory was advanced by Zadeh(1965). It launchesa scientific revolution based on the premise that the key points in human thinking are not numbers, but linguistic terms(Bellman &Zadeh, 1970). During the past decades, numerous decision-making methods based on fuzzy set theory have been proposed and used(Baas &Kwakernaak, 1997; Kuo et al., 2006; Yang et al., 2008; Zimmermann, 1987).Van Laarhovenand Pedrycz(1983)first evolved Saaty's AHP into the fuzzy AHP to solve vague problems that occur during the analysis of criteria and judgment process. Many systematic approachesintegrated the concepts of fuzzy set theoryinto the AHP technique to solve imprecise hierarchical problems in the real-worlddecision making(Dağdeviren&Yüksel, 2008; Sun, 2010; Torfi et al., 2010).Although the fuzzy AHP can deal with the uncertain comparisons using fuzzy scales and has largely been used in related research fields(Dağdeviren&Yüksel, 2008; Erensal et al., 2006; Lin, 2010), it is difficult to preservea consistent pairwise comparison to ensure the order of the preference intensities in the resultant priorities(Çakır, 2008; Wang & Chen, 2008).

In modeling decision processes, preference relations are the most common representation of information used for solving decision-making problems.Generally, these preference relations can be categorized into multiplicative preference relations(Fan et al. 2006; Herrera et al., 2001), fuzzy preference relations(Berredo et al., 2005; Wang & Fan, 2007), and linguistic preference relations(Herrera & Herrera-Viedma, 2000; Xu, 2005).As mentioned above, the principles of universal design are characterizedasqualitativeparadigm.The decision situation in which the alternatives cannot be assessed precisely in a quantitative manner but may be in a qualitative one, thus the use of linguistic assessments is very appropriate(Delgado et al., 1992; Herrera et al., 1998). The fuzzy linguistic approach is an approximate technique which represents qualitative aspects as linguistic values by means of linguistic variables(Zadeh, 1975; 1976).In thispaper,a novel linguistic assessment approach is presented, which can be used to assist decision makers in assessing product design in terms of the universal design perspective. The remainder of this paper is organized as follows. Section 2 introduces the proposed linguistic assessment approach. Section 3 presents a case study to illustrate the practicability of the proposed approach. Finally, concluding remarks are drawn in Section 4.

2. Outline of the fuzzy linguistic assessment approach

Universal design refers to a broad-spectrum planning idea that can permeate more business practices in more companies to produce buildings, products and environments that are inherently accessible to both the able-bodied and the physically disabled users (Tobias, 1997). The intent of universal design is to simplify life for everyone by making products, communications, and the built environment more usable by as many people as possible at little or no extra cost. Based on the universal design principles and fuzzy linguistic techniques, the implementation methods are illustrated step by step as follows:

Step 1. Select a set of products as decision alternatives for the evaluation.

Step 2. Construct a hierarchy based on the universal design principles.

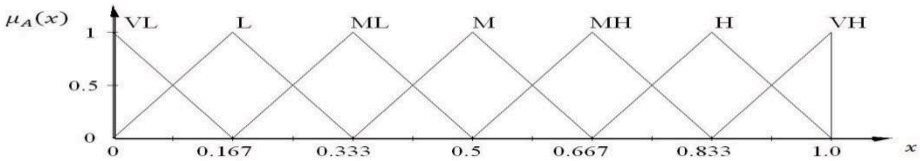
An AHP hierarchy is a structured means of modeling the decision problem. Based on the universal design principles, a simple hierarchy is constructed. The goal is to evaluate the universal design of the selected product alternatives (Level 1). Under the overall goal, the second level represents the criteria based on the seven items of the universal design principles (see Table 3). The product alternatives are linked to the third level.

Step 3. Conduct a universal usability testing.

Universal usability refers to the design of products and services that are usable for every citizen, recognizing the diversity of user population and user needs. Usability testing focuses on measuring a human-made product's capacity to meet its intended purpose. The purpose of the universal usability testing is to measure how well test subjects respond in the criteria of the seven universal design principles. The test subjects are divided into expert and user groups. Both groups of subjects are required to evaluate the selected product alternatives according to the universal usability testing results. A post-test questionnaire is then used to gather feedback on the products being tested. The evaluation grades are 7-point Likert scales, ranging from "strongly disagree" to "strongly agree". Each Likert scale corresponds to a linguistic variable with a crisp number as given in Table 1.

Table 1. Definitions of linguistic variables based on triangular membership functions

Label	Semantic element Likert scale/Level of agreement	Fuzzy number $\propto \in [0.1]$	Crisp number $\propto = 1$	Latent number $\propto = 0.5$
VL	Very low importance/satisfaction Strongly disagree	[0, 0.167]	0	[0, 0.083)
L	Low importance/satisfaction Disagree	[0, 0.333]	0.167	[0.083, 0.250)
ML	Medium low importance/satisfaction Somewhat disagree	[0.167, 0.5]	0.333	[0.250, 0.416)
M	Medium importance/satisfaction Neither agree nor disagree	[0.333, 0.667]	0.5	[0.416, 0.583)
MH	Medium high importance/satisfaction Somewhat agree	[0.5, 0.833]	0.667	[0.583, 0.750)
H	High importance/satisfaction Agree	[0.667, 1]	0.833	[0.750, 0.916)
VH	Very high importance/satisfaction Strongly agree	[0.833, 1]	1	[0.916, 1]



Triangular membership functions of the linguistic sets

Step 4. Determine a set of linguistic weight vectors for the criteria.

The importance (weights) of the criteria is a critical factor in a decision-making process. It must be more objectively and equitably determined. Expert review is a general method of usability testing that relies on bringing experts in with their knowledge and experience in the professional field to evaluate the usability of a product. According to the testing results, experts evaluate the product alternatives through the Likert-type questionnaire. Substituting these scoring data into SPSS software to perform the Pearson distance correlation analysis in pairs, we can derive a proximity matrix thatis regarded as a covariance matrix. Taking advantage of the eigenvalue algorithms, a set of values corresponding to the criteria is derived. These values are used as the weightings determined through the expert group's judgments. They are latent numbers and must be converted into linguistic variables for the following aggregation operation. According to the interval of converting scales given in Table 1, we can determine a set of linguistic weight vectors w_j.

Step 5. Derive a set of linguistic preference vectors for the product alternatives.

The concept of universal design focuses on how a product is usable by all people to the greatest extent possible. It is very important to take account of users' participation in the assessment when conducting a universal design study (Sanford et al, 1998). In this step the priorities for the product alternatives with respect to each criterion are evaluatedby users through the usability testing and the post-test questionnaire. They judge the alternatives according to their actual experience and perception of using the products. The quantitative values are also latent numbers obtained through averaging the user group's preference judgments. After converting these quantitative parameters into linguistic variables, a set of linguistic preference vectors, r_j, can be derived.

Step 6. Aggregate the linguistic variables and rank the alternatives.

In the literature, many aggregation operators have been developed to aggregate information (for details, see Xu& Da, 2003). The fuzzy weighted average (FWA) is one of the important operators which can be used in situations where the arguments are inexact numeric variables (Dong & Wong, 1987; Kao & Liu, 2001). It is a combination of extended algebraic operations to be used in the assessment of alternatives when their corresponding importance (weights) and ratings of criteria are represented by fuzzy numbers. The operation of FWA can be formularized as follows (Vanegas&Labib, 2001):

$$D = \frac{\sum_{j=1}^{m} w_j \cdot r_j}{\sum_{j=1}^{m} w_j} \quad (1)$$

where

D represents the overall desirability of an evaluated alternative;

r_j represents the rating of the j^{th} criterion;

w_j represents the importance (weight) of the j^{th} criterion.

The variables D, r_j, and w_j are fuzzy numbers. It is quite a problem how to perform arithmetic operations with such fuzzy numbers when dealing with the aggregation of linguistic information (Bonissone, 1982). Based on the extension principle (Zadeh, 1965; 1975; 1976), the fuzzy arithmetic operations have been defined to manipulate fuzzy numbers. Besides, according to Klir and Yuan (1995), any fuzzy number can be completely defined by its family of α-cuts, and the extended algebraic operations can be defined based on arithmetic on intervals and assuming that fuzzy numbers are represented by continuous membership functions. The fuzzy set obtained by the four arithmetic operations on fuzzy numbers A and B on $\mathcal{R}$, is defined by its α-cuts. For the purpose of algebraic operations with fuzzy numbers, an arithmetic operation on fuzzy numbers A and B can be reduced to operations on intervals $A_\alpha = [a, b]$ and $B_\alpha = [c, d]$.

Through the arithmetic operations, the family of α-cuts defined as a resultant membership function of the evaluated alternative can be presented in a membership function curve, and it also can be classified as a fuzzy number. In order to obtain a quantitative value of the resultant membership function, the center-of-gravity method known as "defuzzification" is used in this study. The formula of the center-of-gravity method can be expressed as below:

$$\bar{x} = \frac{\int_a^b m(x) \cdot x\,dx}{\int_a^b m(x)\,dx}$$

(2)

where

$m(x)$ represents the degree of membership of the (crisp) variable x;

a and b are respectively the lower and upper limits of the support of the fuzzy number.

3. Case study

This section conducts an empirical study to illustrate the implementation of the proposed approach. The aim of this experiment is to assess the most desirable alternatives from a set of selected products in terms of the universal design perspective. The experiment consisted of two parts: (1) a pilot test to determine the importance (weights) of the criteria, and (2) the universal design assessment for the selected product alternatives.

3.1. Participants

The empirical study involved 3 experts in the pilot test and 20 users in the universal design assessment. The experts were qualified with at least 5 years of personal work experience and are familiar with the unifying principles of universal design. A total of 20 subjects including 18 able-bodied and 2 physically disabled (1 hearing-impaired and 1 right-forearm-impaired)users participated in the universal design assessment. These subjects consisted of 11 females and 9 males, ranging in age between 12 and 68 years (Mean=26.7, S.D.=12.53).

3.2. Product alternatives

Six handy staplers were selected as product alternatives to conduct the universal design assessment. The specifications of the product alternatives are listed in Table 2.

Table 2. List of product alternatives for the universal design assessment

Alternative 1	Alternative 2	Alternative 3
 KW-triO 5109T	 MAX HD-10F	 Hippo stapler CG-ST-108
Size: 97mm(L)×23mm(W) ×41mm(H); Weight: 55g	Size: 95mm(L) ×25mm(W) ×50mm(H); Weight: 105g	Size: 115mm(L) ×60mm(W) ×45mm(H); Weight: 72g
Alternative 4	Alternative 5	Alternative 6
 SDI NO.1113C	 SIMBALION HS-10	 PLUS ST-010A
Size: 80mm(L) ×30mm(W) ×55mm(H); Weight: 90g	Size: 98mm(L) ×20mm(W) ×46mm(H); Weight: 62g	Size: 75mm(L) ×25mm(W) ×47mm(H); Weight: 75g

3.3. Usability tasks

Setting up a usability test involves carefully creating a scenario or realistic situation. The usability tests required participants (both the experts and the users) to perform defined tasks with each of the selected products. Before the usability test began, the experimenter provided a summary of the procedure. Participants used each of the selected staplers to staple five sheets of paper (A4 size) for at least ten times. This task also asked them to add staples inside the stapler before proceeding and draw out the rest after completing the stapling. After having finished the testing task, a questionnaire was provided to the participants immediately (see Table 3). This questionnaire was constructed according to the goal of the usability testing and the proprieties of the selected products corresponding to the universal design principles.

Table 3. Likert-type questions corresponding to the criteria

	Criterion	Question
1	Equitable use	This stapler is useful and attractive to me.
2	Flexibility in use	This stapler accommodates my preferences and I can use this product in whatever ways are efficient and effective for me.
3	Simple and intuitive use	I can easily and intuitively identify the features of this stapler in order to use it.
4	Perceptible information	I can clearly use the stapler and replenish the staples, regardless of ambient conditions.
5	Tolerance for error	If I make a mistake when using this stapler, it will not injure me.
6	Low physical effort	I can use this stapler with less effort and without causing hand pain from repetitive stapling.
7	Size and space for approach and use	This stapler fits my hand size and I can use it in any posture.

3.4.The pilot test

The purpose of the pilot test was to determine the importance (weights) of the criteriathroughexpert evaluation. The three expertsdirectly evaluated the selected product alternatives according to the usability testing results. The means of the expert group's quantitative judgments corresponding to each criterion were classified as the following matrix.

$$X = \begin{bmatrix} 0.444 & 0.444 & 0.611 & 0.611 & 0.444 & 0.556 & 0.722 \\ 0.778 & 0.833 & 0.944 & 0.944 & 0.889 & 0.944 & 0.778 \\ 0.278 & 0.167 & 0.333 & 0.111 & 0.222 & 0.111 & 0.278 \\ 0.833 & 0.833 & 0.889 & 0.944 & 0.889 & 0.922 & 0.944 \\ 0.278 & 0.389 & 0.611 & 0.389 & 0.389 & 0.389 & 0.667 \\ 0.722 & 0.722 & 0.833 & 0.833 & 0.833 & 0.778 & 0.944 \end{bmatrix} \quad (3)$$

Substituting these scoring data into SPSS software to perform the Pearson distance correlation operation, we can obtain aproximity matrix as below:

$$R = \begin{bmatrix} 1.000 & 0.828 & 0.569 & 0.749 & 0.920 & 0.762 & 0.000 \\ 0.828 & 1.000 & 0.954 & 0.932 & 0.974 & 0.971 & 0.411 \\ 0.569 & 0.954 & 1.000 & 0.887 & 0.861 & 0.933 & 0.488 \\ 0.749 & 0.932 & 0.887 & 1.000 & 0.846 & 1.000 & 0.554 \\ 0.902 & 0.974 & 0.861 & 0.846 & 1.000 & 0.877 & 0.309 \\ 0.762 & 0.971 & 0.933 & 1.000 & 0.877 & 1.000 & 0.457 \\ 0.000 & 0.411 & 0.488 & 0.554 & 0.309 & 0.457 & 1.000 \end{bmatrix} \quad (4)$$

Taking advantage of the eigenvalue algorithms, we can derive the following set of eigenvaluesand their corresponding eigenvectors.

$$\lambda_{Stapler} = \{5.554, 1.077, 0.268, 0.16, -0.04, -0.004, -0.016\} \Rightarrow \lambda_{max} = 5.554 \quad (5)$$

By calculating the absolute values of the eigenvectors corresponding to the maximum eigenvalue, we determined a set of the priorities of the principal diagonal elements. The obtained values were then converted into linguistic weight variables as listed in Table 4.

Table 4. Linguistic weight variables (w_j) for the criteria of the universal design assessment

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7
Weight	0.345	0.423	0.395	0.411	0.404	0.417	0.2
Order	*6*	*1*	*5*	*3*	*4*	*2*	*7*
w_j	ML	M	ML	ML	ML	M	L

3.5.The universal design assessmentfor the selected product alternatives

According to the usability testing results, the user group's quantitative judgments with respect to the product alternatives were categorized and converted into linguistic preference variables as listed in Table 5.

Table 5. Linguistic preference variables (r_j) for the product alternatives with respect to each criterion

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7
Alternative 1	M (0.542)	MH (0.583)	MH (0.65)	MH (0.692)	M (0.575)	MH (0.633)	MH (0.683)
Alternative 2	MH (0.7)	MH (0.742)	H (0.758)	H (0.8)	MH (0.683)	MH (0.7)	MH (0.7)
Alternative 3	ML (0.408)	L (0.233)	ML (0.375)	L (0.242)	M (0.425)	ML (0.325)	ML (0.267)
Alternative 4	H (0.775)	H (0.758)	H (0.783)	H (0.783)	MH (0.708)	MH (0.7)	MH (0.608)
Alternative 5	M (0.492)	MH (0.583)	MH (0.658)	MH (0.617)	M (0.525)	M (0.483)	MH (0.633)
Alternative 6	MH (0.7)	MH (0.642)	H (0.808)	MH (0.717)	MH (0.675)	MH (0.7)	MH (0.717)

Based on the results of Table 4 and Table 5, substituting these linguistic variables into Formulas (1) to perform the FWA operation, we deriveda set of membership functions, which are presented in membership function curves as shown in Figure 1.

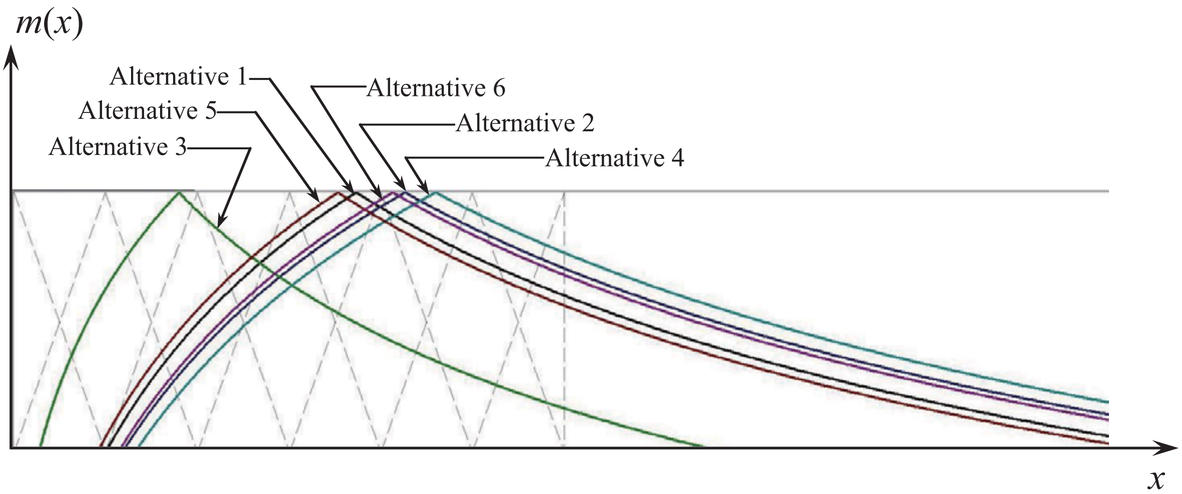


Figure 1. Resultant membership function curves

Further defuzzificating the fuzzy numbers by using the center-of-gravity method, we obtained a set of quantitative values as well as ranked the product alternatives. The final results of the universal design assessment are listed in Table 6.

Table 6. Final results of the universal design assessment

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Quantitative values	0.885	0.999	0.479	1.068	0.845	0.971
Rank	4	2	6	1	5	3

According to the assessment results, we found that the best example is Alternative 4 while the worst is Alternative 3. Alternative 3 has a cute hippo-like appearance but lacks for something about the universal usability. Alternative 4 is a flat-clinch stapler that the staples are clinched flat on the back, reducing the risk of staple scratches. In addition, its twin-lever mechanism can cut stapling effort and reduce hand pain from repetitive stapling. Although Alternative 2 (Rank 2) also provides the same functionality, it is bigger and heavier than Alternative 4 so that it is less equitable and flexible for users to grip and use. As a whole, the universal design assessment has shown a credible result.

4. Concluding remarks

This study considers the aggregation operator as linguistic variables, and uses the fuzzy weighted average method to perform preference aggregation. In practice, the proposed approach not only considers both the relative important of the criteria and its achieved performance, but also conveys the influence of the evaluator's evaluation attitudes. It can flexibly reflect any evaluator's evaluation attitudes such as open, neutral or rigorous. In conclusion, the proposed approach can make an objective assessment that approaches a real decision making situation. It has the potential to be a useful decision-aiding tool for dealing with complex assessment problems. In addition to universal design, this fuzzy linguistic approach can be used to systematically assess alternatives from criteria relevant to a set of qualitative attributes.

Acknowledgements

This research was financiallysupported by the National Science Council of Taiwan under grant NSC 100-2221-E-214-073.

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國科會補助計畫衍生研發成果推廣資料表

日期:2012/07/15

國科會補助計畫	計畫名稱: 語言評判技術於通用設計產品評價之應用研究
	計畫主持人: 周志榮
	計畫編號: 100-2221-E-214-073- 學門領域: 人因工程與工業設計

無研發成果推廣資料

100 年度專題研究計畫研究成果彙整表

計畫主持人：周志榮			計畫編號：100-2221-E-214-073-				
計畫名稱：語言評判技術於通用設計產品評價之應用研究							
成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
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國外	論文著作	期刊論文	1	1	100%	篇	Jyh-Rong Chou (May, 2012). A linguistic evaluation approach for universal design. Information Sciences 190, pp. 76-94. (SCI) Impact Factor: 2.836, Rank Factor: 10/128, Subject Categories: COMPUTER SCIENCE, INFORMATION SYSTEMS.
		研究報告/技術報告	0	0	100%		
		研討會論文	1	1	100%		Jyh-Rong Chou (July 2011). Universal Design Assessment based

							on Fuzzy Linguistic Techniques. 2012 International Conference of Organizational Innovation, pp. 1571-1584.
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
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其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)		本研究部分成果整理完成’’’’’’’’’ Universal Design Assessment based on Fuzzy Linguistic Techniques’’’’’’’’’ 論文,發表於 2012 International Conference of Organizational Innovation 國際研討會,並獲得 Outstanding Paper Award.					

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

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   研究成果整理成兩篇論文,分別為’’’’’’’’’ A linguistic evaluation approach for universal design’’’’’’’’’ 發表於 Information Sciences 學術期刊；及’’’’’’’’’ Universal Design Assessment based on Fuzzy Linguistic Techniques’’’’’’’’’ 發表於 2012 International Conference of Organizational Innovation.

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