# Fuzzy Inferencing in the Web Page Layout Design


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**Abstract.** The Web page layout design is a complex and ill-structured problem where the evolving tasks, inadequate information processing capabilities, cognitive biases and socio-emotional facets frequently hamper the procurement of a superior alternative. An important aspect in selection of a superior Web page layout design is the evaluation of its fitness value. Automating the fitness evaluation of layouts seems to be a significant step forward. Such efforts require quantification of highly subjective Web page design guidelines in the form of some fitness measure. These Web usability and design guidelines come from experts who provide vague and conflicting opinions. This paper proposes the utilization of fuzzy technology in modeling such subjective, vague, and uncertain Web usability and design guidelines.


## 1 Introduction

The Internet is an extraordinarily powerful, flexible, personalized as well as interactive marketing and merchandising tool enabling exploration of new markets and paradigms [1], [15]. The annual volume of E-Commerce (EC) is expected to soon reach trillions of dollars [25]. The uninterrupted development of such sophisticated Web applications has created an intense interest in formulating and formalizing the Web page layout (WPL) design guidelines. However, the usefulness of these guidelines is partially limited by the inability of the Web site designers to understand and quantify the system related characteristics [1].

The WPL design is a complex and ill-structured problem where the evolving tasks, inadequate information processing capabilities, cognitive biases and socio-emotional facets frequently hamper the procurement of a superior WPL design [1]. The designers of online stores are facing high cognitive overhead in acquiring, remembering, understanding, and applying the vast body of information available for usability and merchandising considerations. Consequently, there is a pressing need for aiding the WPL designers through various means. One such aspect is the evaluation of fitness values of the available layout alternatives for selecting a superior WPL design. The ideal course would be the visual evaluation of the WPL designs by a panel of experts and user testing [7], [8]. However, such an approach might not be practical in face of limited resources etc. Consequently, some system of automatically computing layout fitness in a swift, objective, and less resource intensive manner is crucial [8]. Such an automatic evaluation of layouts requires quantifying highly subjective WPL design guidelines coming from experts having vague and conflicting opinions. A range of automated Web site usability assessment tools are available; however, those are far from fully automating the usability assessment process due to the inability to incorporate many key usability guidelines in the evaluation mechanism [8]. Furthermore, most Web usability and design guidelines are vague, differing, and even conflicting.

Here we identify a potentially very prolific application area for fuzzy logic (FL), namely, the modeling of the Web usability and design guidelines. To the best of our knowledge, no study has examined this prospect. The idea is to use fuzzy sets, rules and preferences in a Fuzzy Preference Agent (FPA) in obtaining penalties/rewards of the WPL design fitness function for evaluation and comparison purposes. Such an FPA can also be used to generate important decision parameters for some automatic layout generator. The potential for utilizing FL arises from its natural representation of human conceptualization and partial matching. We deem FPA to be a logical component for any Web usability analysis tool. We believe, this approach would augment the efficiency of WPL designers and spur future research in related areas.

This paper is organized as follows. Section 1 provides the motivation. Section 2 deals with the importance of the Web usability and design guidelines. Section 3 outlines some general Web usability and design guidelines and sources of uncertainty in those. Section 4 outlines potential of using FL in tackling sources of uncertainty in the WPL design problem. Section 5 gives an illustrative example for the use of FL in the WPL design problem. Section 6 concludes the paper with some future research directions.

## 2 Significance of Web Page Usability

The principal economic effect of EC is the dramatic increase in the competitive pressure [11]. The personal customer-business relationship in EC builds high customer expectations [15]. Customer engagement and retention are key issues in any business initiative. However, the high customer acquisition costs and low conversion rates hinder profitability of online stores and pronounce the need for more usable EC sites [16]. Studies have shown that visitors form distinctive emotional impressions from the Web site design [6].

A Web page is plagued by the feel of the 'keyhole view' resulting from the spatial and temporal separation of display information, underscoring the need for 'usable' designs [4]. Inadequately designed Web interfaces could result in productivity losses, user frustration, lost business, lost trust etc [8]. Consequently, the knowledge about the customer is deemed fundamental for the development of viable EC solutions. Significant efforts are undertaken towards creating Web experiences that are easy and enjoyable for the users as evident from continued development of sophisticated EC sites [21]. However, little has been done to help designers of the online stores who eventually use a vast body of both prescriptive and descriptive literature [1]. Accordingly, the Web store usability remains a serious issue and some means for automatically evaluating layout designs against the available WPL design guidelines seems to be an important step forward [1], [8], [11].

## 3 Web Page Usability and Design Guidelines

Interaction with computers is an important consideration in the Web usability and a substantial research literature is present on both Web usability and human-computer interaction [2], [5], [13], [19], [20], [23]. A more recent and thorough review of such design guidelines can be found in [8].

Designing a Web site involves two main issues, i.e. the content and the form. Despite all the importance of the content, there is no substitute for a carefully planned Web site design and a well thought layout. This has much to do with the 'usability', i.e. accommodating users with different skills, knowledge, age, gender, handicaps, literacy, culture, income, etc. The goal is to build a hierarchy of menus and pages that look natural and well structured to the user. Some examples of important Web page usability dimensions include Symmetry (in terms of Colour, Shape, Texture, Size etc.), Spacing, Page Dimensions, and Consistency [8].

However, despite recent intense interest in the Web usability and design guidelines motivated by EC, the usefulness of such guidelines is partially limited by the difficulty in understanding and quantifying the system-related characteristics. The Web page layout design problem is so vast in scope, involves such myriad of tangible and intangible factors, and contains such a high degree of dynamism that validity of any proclaimed optimal solution could easily be challenged [3]. Furthermore, the users of Web sites are generally non-homogeneous coming from a wide variety of backgrounds and cultures, accompanied by varying and conflicting mental and social metaphors etc. Moreover, they have conflicting needs, preferences, and opinions. For instance, Red represents danger in the United States and happiness in China. Perhaps, these reflections have played their role in the reluctance to the study of WPL design problem in an analytical manner. Consequently, there has been relatively little work in this direction.

Recently a methodology for automatically evaluating page layouts has been proposed within the context of electronic albuming involving calculation of a fitness function based on crisp values of graphic design preferences supplied by the user [7], [14]. However, a big hurdle in utilizing such an approach is the extraction of knowledge from human experts who think in an imprecise or fuzzy manner. Moreover, the WPL design guidelines provided by the relevant literature and experts are often vague and conflicting, or 'fuzzy', in nature. Several examples can be cited to demonstrate the ambiguous nature of Web usability and design guidelines. For instance, several experts and studies suggest that fast download time is an important aspect in user satisfaction [19]; however, other studies have found no such correlation [24]. Another example is of the depth versus breadth trade-off in the web site design. Several experts agree that Web sites should be broad rather than deep [12], [22]. However, Web sites with more than 16 navigation bar links confuse the user [2]. Such examples articulate the need of some uncertainty handling mechanism. FL provides a way of working with these imprecise and uncertain cases.

### 3.1 Managing Uncertainties

Uncertainty in the domain knowledge can result from incomplete, inconsistent, imprecise or vague information [17]. WPL design guidelines are inherently imprecise, vague and ambiguous [1]. Consequently, any Web usability evaluation mechanism should have some way of coping with such uncertainites.

The majority of theories devised to handle uncertainties are quantitative in nature where a methodology is devised to quantify uncertainties in form of some measures and to propagate/combine these measures during reasoning[19]. Examples include the Bayesian, Certainty Factors, Dempster-Shafer, Fuzzy Sets, and Belief Networks approches.

Bayesian is a probabilistic approach requiring a very large number of probabilites and, hence, large number of experiments. Estimation of such probabilities by human experts may be inconsistent and biased. Furthermore, the approach is valid only under the simplifying assumption that the presence of evidence also affects the negation of conclusion, which is not valid in most instances. In addition, Bayesian approach is not well-suited for providing explanation facilities [17].

In Certainty Factors (CF) approach, the knowledge is expressed in the form of rules and a confidence factor associated with each rule. It does not require statistical basis for supplying beliefs in events and allows simultaneous rule representation and quatification of uncertainty making it simpler and efficient compared to Bayesian approach. However, CF approach is not built on a solid theoretical foundation and results in many weaknesses. For instance, CF approach works under the implicit assumption of independance among hypotheses [19].

The Dempster-Shafer (DS) theory of evidence addresses some of the weaknesses of the probabilistic approach including the representation of ignorance, the unnecessary requirement that the sum of beliefs in an event and its negation be 1 etc. However, it does not specify how the probabilities are to be computed or how the results are to be interpreted. Furthermore, in certain instances, obviously incorrect conclusions can be reached [19].

FL is a set mathematical principles for knowledge representation based on degrees of membership rather than on the crisp [17]. Experts think in imprecise terms, such as very high and low, fast and slow, etc. and fuzzy set theory provides means for computing and reasoning naturally with words. It is concerned with the use of fuzzy values that capture the meaning of words, human reasoning and decision-making. It has proved itself successful in automated reasoning [9], [10], [26]. In such dynamic domains as Web page layout design where very little or no a priori knowledge is available, the probabilistic approach is rendered ineffective as it requires repeated experimentations. However, we see immense potential in using partial matching techniques provided by fuzzy set theory.

## 4 Fuzzy Inferencing

One way of evaluating the overall quality/utility of a Web page is to develop a fitness function comprising of weighted sums of utilities arising from various WPL usability dimensions. The weights would represent the preferences provided by experts. These preferences come from a wide variety of perspectives belonging to various domains running across varying, overlapping, and/or conflicting objectives. A set of exact rules cannot be defined for each possible situation in the Web page layout design problem. Furthermore, such decisions are based more on human intuition, creativity, common sense, and experience rather than the availability and precision of data. The inherently imprecise nature of preferences in the Web page layout design problem renders fuzzy technology an excellent candidate for modeling those preferences. It is also expected to reduce the computational cost substantially while making the representation more realistic [19]. These are outcome of merging of rules in fuzzy knowledge-based systems, by virtue of fuzzy sets, rendering more than 90 per cent reduction in the number of rules [17].

The basic idea of fuzzy set theory is that an element belongs to a fuzzy set with a certain degree of membership. Furthermore, fuzzy set is simply a set with fuzzy boundaries. Thus, a proposition is neither True nor False, but may be partly true or false to some degree. This degree is usually taken as a real number in the interval $[0, 1]$. As an example, experts can describe preferences for the amount of white space in the Web page layout in fuzzy terms as 'small', 'medium' or 'large' (as shown in Fig. 1). A fuzzy set $A$ of universe $X$ defined by a function $ì_A(x)$ is known as the Membership Function (MF): $ì_A(x) : X \quad [0, 1]$. Where $ì_A(x) = 1$ if $x$ is totally in $A$, $ì_A(x) = 0$ if $x$ is not in $A$ and $0 < ì_A(x) < 1$ if $x$ is partly in $A$.

One of the foremost requirements in application of FL is the determination of MFs. It may involve knowledge of one or more experts. Some machine learning approach can also be used to automatically derive fuzzy sets and their MFs. The typical MFs used in fuzzy knowledge-based systems are the triangular and trapezoidal functions as those provide an adequate representation of the expert knowledge and significantly simplify the computational process [17].

We envisage fuzzy preferences taking the form of significance parameters and preference parameters. A *significance parameter* (SP) tells 'how important' certain aspect/criteria is for the overall fitness of the layout. Whereas, a *preference parameter* (PP) tells 'how much' of certain aspect/criteria should be incorporated in the layout generation. A few examples of fuzzy preference parameters in Web page layout design problem are: amount of white space, symmetry, colour scheme, repetition of modules, chronological value, emphasis etc. The FPA would accept fuzzy and/or crisp preferences and transform them in crisp weights, using the fuzzy rules present in the knowledge base, for the use in some layout fitness evaluation function. It should be noted that certain parameters could have significant interaction with one another affecting more than one value of crisp weights used subsequently in layout evaluation phase. The FPA should have some way of handling these interactions and interdependencies. The ability of FL to realize a complex non-linear input-output relation as a synthesis of multiple simple input-output relations can prove invaluable in this regard [19].

## 5 Example

Fuzzy inferencing is the process of mapping a given input to an output using the theory of fuzzy sets. Among various inferencing mechanisms, the Mamdani-style inference method is the most commonly used technique for capturing experts' knowledge allowing for more intuitive and human-like description of expertise involving four steps: fuzzification of inputs, rule evaluation, aggregation of rule outputs, and finally defuzzification [17], [19].

For elaboration purposes, we consider a simple example where the amount of 'white space' and the 'size of the Web page' affect the maximum number of 'page modules' that could possibly be placed on a single Web page. This is an important parameter to be determined. For instance, it would affect the length of chromosome chosen in a Genetic Algorithm (GA) designed to generate layouts automatically. The length of chromosome in a GA has dramatic effect on efficiency and quality of results as it determines the search space in a GA.

Let $x$, $y$, and $z$ (*white_space*, *page_size*, and *page_modules* respectively) be the linguistic variables; *A1*, *A2*, and *A3* (*small*, *medium*, and *large*) be the linguistic values determined by fuzzy sets on the universe of discourse *X* (*white_space*); *B1*, *B2*, *B3* and *B4* (*small*, *medium*, *large* and *ex-large*) be the linguistic values determined by fuzzy sets on the universe of discourse *Y* (*page_size*); *C1*, *C2*, and *C3* (*small*, *medium*, and *large*) be the linguistic values determined by fuzzy sets on the universe of discourse *Z* (*page_modules*). The typical of such MFs is shown in Fig. 1 by a set of arbitrarily chosen MFs for illustration purposes.

Furthermore, we consider a simple two-input one-output scenario that involves the following two rules:

*Rule 1:* IF *x* is *A2* (*white_space* is *medium*)
OR *y* is *B3* (*page_size* is *large*)
THEN *z* is *C2* (*page_modules* is *medium*)

*Rule 2:* IF *x* is *A3* (*white_space* is *large*)
OR *y* is *B4* (*page_size* is *ex-large*)
THEN *z* is *C3* (*page_modules* is *large*)

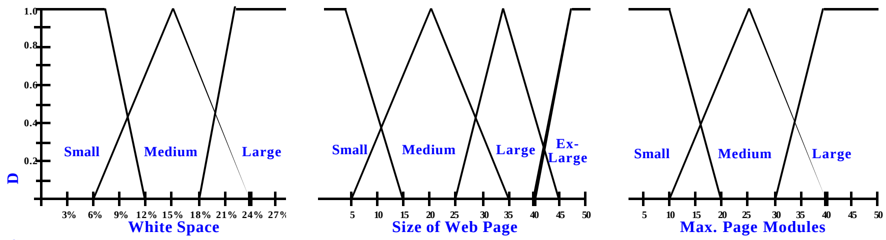


**Fig. 1.** Typical Fuzzy Sets for 'White Space', 'Page Size' and 'Page Modules'.

As a first step, we need to **fuzzify** all the crisp inputs and determine the degree to which these inputs belong to each of the appropriate fuzzy sets. The crisp input *x1* (*white_space* rated by experts as 20%) corresponds to the MFs *A2* and *A3* (*medium* and *large*) to the degrees of 0.6 and 0.2, respectively. Likewise, the crisp input *y1* (*page_size* rated as 44 units) corresponds to the MFs *B3* and *B4* (*large* and *ex-large*) to the degrees of 0.15 and 0.5, respectively.

The **rule evaluation** takes the fuzzified inputs and applies them to antecedents in the fuzzy rules. Here we use the *min* operator to evaluate the fuzzy *OR* operation and the *max* operator to evaluate the fuzzy *AND* operation, respectively. This results in the following:

$$\grave{\imath}_{C2}(z) = max[\grave{\imath}_{A2}(x), \grave{\imath}_{B3}(y)] = 0.6; \qquad \grave{\imath}_{C3}(z) = min[\grave{\imath}_{A3}(x), \grave{\imath}_{B4}(y)] = 0.2$$

The result of antecedent evaluation is applied to the MF of the consequent by either 'clipping' or 'scaling' the consequent MF to the level of the truth-value of the rule antecedent (clipping is used in our example). **Aggregation** is the process of unification of the outputs of all rules. The input to the aggregation process is the clipped or scaled consequent MFs and the output is one fuzzy set for each output variable.

The fuzziness helps us in evaluating the Web page layout design rules; however, the final output of the FPA has to be a crisp number for use in some fitness function. The most popular technique for **defuzzification** is the 'centroid' technique where a vertical line carves the aggregate fuzzy set into two equal masses. Using the Mamdani technique in the given example, the crisp value for the *page_modules* comes out to be about 27.

In this manner, an automatic layout generator could adapt in terms of 'page modules' based on preferences furnished by experts/users. This example illustrates how vague linguistic rules can be used to derive important and useful crisp values. Likewise, the FPA could furnish other crisp weights to be used in evaluation of the fitness of a Web layout design.

## 6 Conclusion

We have proposed the use of Fuzzy Logic to model Web usability and deign guideline, a potentially very prolific and open application area for fuzzy logic. A rough framework for such an application has been chalked out and the applicability of FL is illustrated using an example. Testing, validating, and tuning of FPA requires building some sort of Layout

Design Generator that utilizes preferences furnished by FPA. For instance, the crisp weights could be used to calculate some layout fitness/utility function in the layout generator. Consequently, we deem some Intelligent Layout Generator to be an important extension of this framework. We believe that this approach is applicable to other layout design domains and is expected to spur and facilitate future research in related areas.

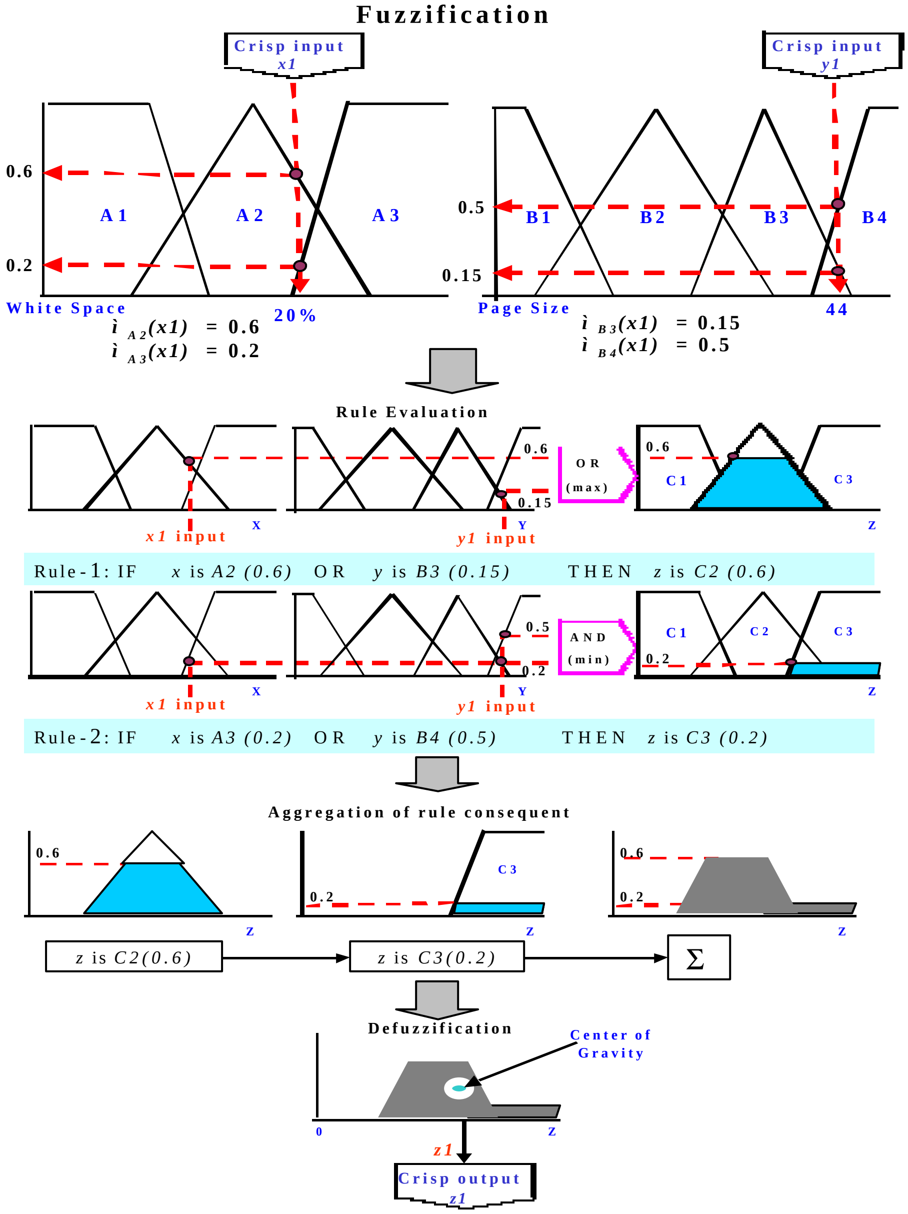


**Fig. 2.** Example of Mamdani style Fuzzy Inferencing in the Web Page Layout Design

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