Fuzzy Logic-Based Evaluation Model of Handwritten Font Sizes Readability on Extra Small Devices

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Abstract—Handwritten fonts are appealing to designers, but their application in web design can cause a readability problems. Different handwritten letter cuts in different font sizes are not equally readable on all screen types. The problem often occurs on extra small devices such as mobile phones. Therefore, it is necessary to choose the combination of the font type and appropriate font size that will ensure responsiveness and be readable on different devices, especially the small ones. For this purpose, a study of readability of monoline handwritten font in seven letter cuts (thin, ultra-light, light, regular, semi-bold, bold, and ultra-bold) in several font sizes was conducted. Variable font was used because it contains all style versions of one typeface family, as opposed to standard font families that use different files for each style version. Also, variable font is suitable for use on web because one file with all the necessary typeface styles is significantly smaller in size than classic families with multiple files which shortens the font loading time. Furthermore, model of readability evaluation using the fuzzy logic based postprocessing method for segmentation values related to evaluation criteria is proposed. Prototype of a variable handwritten fonts are tested in responsive web environment, using CSS technology. The results show that handwritten font size readability evaluation has measurable output because the score combine various numeral factors affecting the readability of particular font size in several letter cuts. Using of proposed model in short time can show readability level of some font type in some font size on a new responsive web suitable for different screen sizes, including extra small devices.

Keywords—artificial intelligence, responsive web, mobile phones, letter cut, variable font

1 Introduction

In the past, users of multimedia content were satiated with a generic offer, and today they expected customized content. Thus, a space was opened up to generate a model that is capable of copying the logic of individual user steps to create intelligent content in real time. This content must also be optimized to be displayed equally on all devices. To achieve this, it is necessary to integrate personalization technologies that operate on the principle of ontology and semantically based information.

It is important to point out that web technology using HTML and CSS technologies can facilitate the inclusion of a variety of content while support for multi-platform responsive design can be more easily achieved by using development frameworks for the user side.

According to the newest version of OpenType standard [16] variable font is a single font file which contains all style versions of one typeface family, as opposed to standard font families that use different files for each style version. This characteristic is advantageous in web use, because of the fact that one file with all typeface styles (bold, italic, regular etc.) is significantly smaller in size than classic families with multiple files. The time needed for loading fonts is shorter which enables wide range of typographical use on various devices.

Therefore, space was opened up for extensive research on how to integrate the optimization and personalization of multimedia content into a responsive web environment. In the first part of the research, the emphasis is on typography because text is still the dominant element of a website. However, a step forward has been made and a variable handwriting font that is not so common in web design has been tested. Responsiveness from the aspect of writing cut and writing size was observed. Readability from the aspect of a written cut is described in the paper "Readability evaluation of variable handwritten fonts in a responsive web environment using fuzzy logic". The next step in the research will include static images, as well as animations and video elements. The results of this extensive research will contribute to the easier creation of optimized personalized content in a responsive environment that requires the creation of a website using a single code for all devices.

2 Literature review

Numerous authors have dealt with responsive web as well as variable fonts. But there are few papers in which these two key elements are related and placed in the function of readability of the text. Therefore, in order to create and test a technological model that is capable to create intelligent and readable content for responsive environment it was necessary to study two different segments of the past research. Also, there are many works that describe the classical methods of assessing the readability of the text and they date back to the 60s of last century. Data-driven methods have been researched for the last twenty years, to which the development of artificial intelligence has contributed. The works that guided this research are described below.

Analysis of web content delivery effectiveness and efficiency in responsive web design using material design guidelines and user content design is described by Pinandito et al. [18]. Authors compared the effectiveness and efficiency of a web page that is being displayed on a computer screen, tablet, and smartphones. Implementation od mentioned two approaches in the design were evaluated and presented. The benefit of using VISER to support automated visual verification of layout failures in responsively designed web pages was revealed in experiment conducted on 20 web pages [5]. Similar investigation was conducted by Walsh et al. [24]. They present an automated approach that extracts the responsive layout of two versions of a page and compares them. In other paper the same authors explored two different usage scenarios for tools for supporting the detection of failures in layout on a different devices [23]. Almeida and Monteiro [4] described the role of responsive design in web development that offering a good user experience and increasing accessibility stands out as being the most important advantages.

Sittisaman and Panawong [21] presented the development of a real-time information content recommendation system on smart phone using responsive web design. Their responsive web design model using Bootstrap framework and adapt the display of websites for various screen sizes of smart phones. A study on mobile-first based responsive web design was conducted by Lee and Noh [14] Authors offered responsive web design which is capable flexibly responding to various devices with single source, from a mobile-first perspective.

Leiva [15] described responsive text summarization approach to web design aimed at allowing desktop web pages to be read in response to the size of the device a user is browsing with.

Displaying content on large screens is also demanding, so it is important to notice paper of Perakakis and Ghinea [17]. They propose the use of responsive web design, a method that has become standard in mobile devices, saving the need of developing custom TV-specific websites or Apps.

Typography for the web is really hard to design anywhere other than a browser. Huelves and Marco [12] presented a model that lays the foundations for providing variable fonts with a semantic use in graphic interfaces, establishing a relationship between typography and the data collected by different sensors.

Artificial intelligence is commonly used method for web analysis and development. The group of authors [9] used artificial intelligence technology to develop of multi-language interactive device for visual impairment person.

Rekik [19] proposes an approach based on fuzzy Analytic Network Process (fuzzy ANP) and the fuzzy Technique for Order Performance by Similarity to Ideal Solution (fuzzy TOPSIS) methods to rank and assess E-commerce web sites.

Hanin, Amani and Fakhri [8] proposed a new improvement in the TCP algorithm that employed fuzzy logic to predict packet loss and avoid congestion. For this purpose, they have used tree metrics such as stability, energy, and signal strength to use in fuzzy logic systems.

Garcia-Plaza et al. [7] defined a set of criteria to exploit the information provided by some page elements and introduced a fuzzy combination of these criteria that evaluate within the context of web page clustering tasks. Their proposed approach, called abstract fuzzy combination of criteria (AFCC), can adapt to datasets whose features are distributed differently, achieving good results compared with other similar fuzzy logic-based approaches. Also group of authors [1] used the Fuzzy logic Analytic Hierarchy Process (Fuzzy-AHP) mechanism to determinate sustainability goals and long-term impacts which could prove to be value for improving sustainability of the web applications. Honamore and Rath [10] used Hidden Markov Model (HMM) and Fuzzy logic prediction model to predict reliability of web services. Also, Agusta et al. [2] proposed a model of effort estimation for web-based mobile application developed using object-oriented approach based on fuzzy logic in order to compare and evaluate two metrics. Tehsin et al. [22] made one step forward and used fuzzy logic for segmentation and extraction text elements from images and videos.

Al-Shatnawi and Al-Saqqar [3] suggested a holistic model for recognition of handwritten Arabic text based on the local binary pattern technique (LBP), and two machine-learning approaches: Support Vector Machines (SVM), and Artificial Neural Network (ANN).

3 Methodology

3.1 Problem formulation

Conti Readability is crucial part of web usefulness and is closely related to suitability, clarity and resolution which are other components of the typography. Current traditional methods of readability evaluation such as McCall-Crabbs Standard Test, LIX formula or Dale-Chall formula do not provide precision readability score compared to data-driven methods. Artificial intelligence provides cheaper and faster evaluation process with easier results analysis. From this reason, there is a need to develop a model of readability evaluation that is based on mathematical principles, linguistically understandable, quick, precise, and allowing to get single-value score. It is important to point out that evaluating the readability of text in a responsive web environment is only the first step in modeling optimized and personalized web content for each individual user and on different devices.

3.2 Model of fuzzy readability evaluation

Fuzzy logic principle and model definition. Fuzzy logic represents a new approach to the problems of managing complex systems, so as a fuzzy expert inference system it is suitable for solving the problem of readability detection in accordance with the needs of users of different devices. It is convenient for the reason that it approaches the measurement of things by scaling based on scales. Unlike classical logic, which uses only two values, 1 (true) and 0 (false), fuzzy logic increases the range of values to all real numbers between 1 and 0.

The standard logistic function is defined as:

$$S(x) = \frac{1}{1 + e^{-x}} \tag{1}$$

which has the following symmetry property:

$$S(x) + S(-x) = 1 \tag{2}$$

and from this it follows that:

$$(S(x) + S(-x)) \cdot (S(y) + S(-y)) \cdot (S(z) + S(-z)) = 1 \tag{3}$$

General fuzzy model consists of crisp input values, fuzzification, fuzzy inference engine, defuzzification, and crisp output value. Inputs are numerical values which are fuzzified by fuzzifier meaning that the inputs are represented as fuzzy logic. This process is known as the fuzzification. In next step refined rules and the fuzzification results are collectively fed to the fuzzy reasoning system. The rules where the conditions are satisfied for the input are fired. Further, the application of correlation, inference, and defuzzification is done. A degree of membership describing the results is obtained and converted back into the crisp value and this process is named defuzzification [13].

In addition to the above, a flow diagram can be generated (Figure 1).

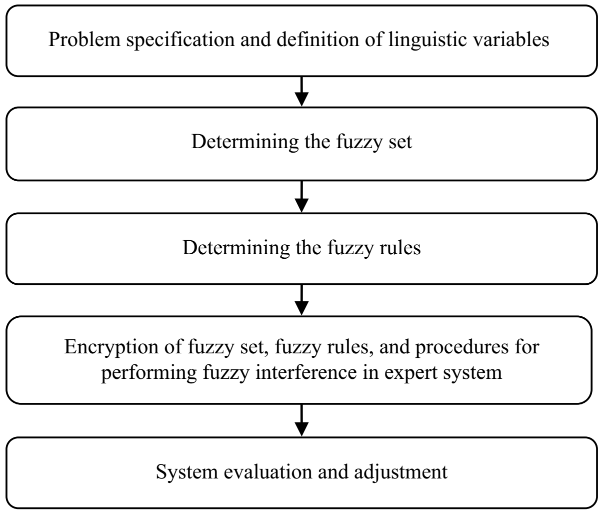

Fig. 1. Fuzzy-logic flow diagram

Model of fuzzy readability evaluation is based on generic model with set of criteria selected according to the characteristics of the target environment (Figure 2). So, the methodology of fuzzy readability evaluation provides guideline how to perform this process and finally obtain readability score such as understandable results. Hub and Zatloukal [11] had a similar approach when analyzing the usability of the web. The model of fuzzy readability evaluation is a multi-layer process of obtaining readability score and the key aspect of accuracy and significance of the fuzzy readability evaluation model is the proper determination of the criteria. The model therefore has multiple inputs and single output. In next step it is necessary to define the empirical scale that explains which values represent the evaluation expressions. This is done by inquiring a group of testing users that evaluates the readability both by using word expression and by numeric score of each criteria [11].

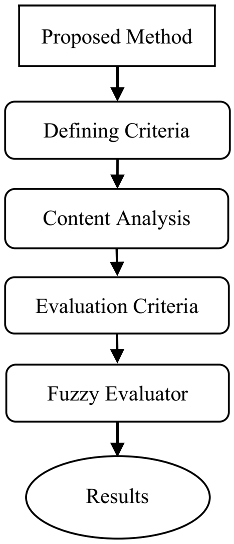

Fig. 2. Model of readability evaluation

Object of the evaluation. This paper explores readability of prototype of a variable font tested in responsive web environment, using CSS technology (Figure 3). Variable font is a single font file which contains all style versions of one typeface family, as opposed to standard font families that use different files for each style version. Therefore, they are suitable for use on web because one file with all the necessary typeface styles is significantly smaller in size than classic families with multiple files. This shortens the font loading time, which enables wide range of typographical use on various devices. Applying variable fonts opens advanced possibilities to designers when designing for web.

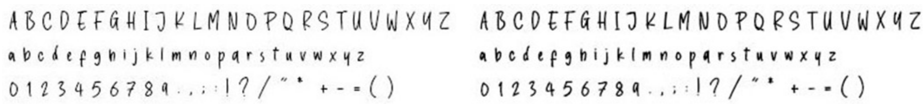

Fig. 3. Tested variable handwritten font, regular cut, and bold cut

Regarding Rutter [20] typography prototype should be a single web page that preferably consists of some real content and be tested in different contexts: different devices, different screens, different reading distances. Therefore, a test website was created with a variable handwritten font in two cuts, regular and bold, in four font sizes 14 pt, 22 pt, 26 pt, and 34 pt (Figures 4 and 5). Typography is the foundation of design by starting with the fundamentals, the content and the typography, and adding hierarchy before layout and color. For this purpose, it is important to test the size of the characters before the cut type. Selected font sizes were used for text, headers, subheadings, and Selected font sizes were used for text, headers, subheadings, and highlighted headings.

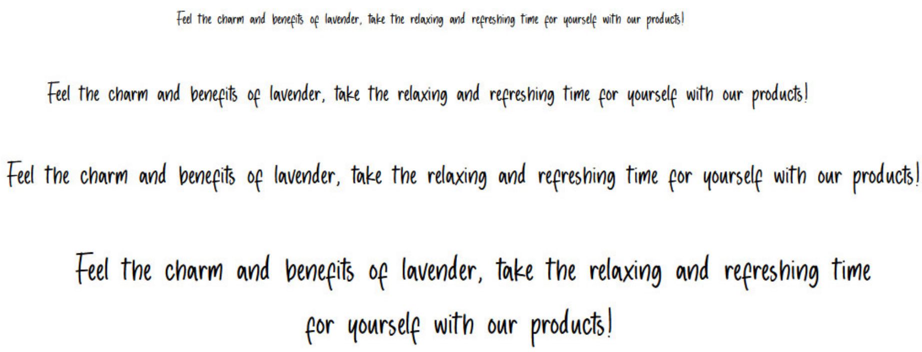

Fig. 4. Tested web text, regular cut in 14 pt, 22 pt, 26 pt, and 34 pt

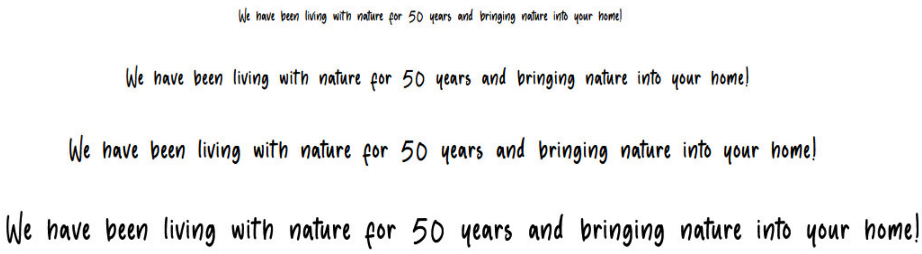

Fig. 5. Tested Web text, bold cut in 14 pt, 22 pt, 26 pt, and 34 pt

With more and more web-enabled gadgets web design has to be flexible and adaptable to different screens and devices. This is enabled by responsive design. Four devices with four different screen sizes were used in this study as shown in the Table 1.

Table 1. Max screen width of tested devices

XS **< 768 px**	**SM** **≥ 768 px**	**MD** **≥ 992 px**	**LG** **≥ 1200 px**
Extra small devices (mobile phones)	Small devices (tablets)	Medium devices (desktops)	Large devices (desktops, TV screens)

Evaluation criteria. As stated in chapter 3.1, it is first necessary to determine the problem input and output variables and their range. In this study, these were two sets of four main linguistic variables, text readability in letter sizes 14 pt, 22 pt, 26 pt, and 34 pt (Table 2), the same set for each font cut (regular and bold). Typography readability, typography suitability, typography clarity, and typography resolution could be in one word named text usability. Text usability is directly related to the hierarchy. Too much consistency leads to a monotonous design while too much contrast leads to chaotic noise. One way to balance the contrast and consistency is to create a regular typographical hierarchy, where type fluidly scales from the top level (level 1 heading) into the body content (paragraphs) [6].

Table 2. Evaluation criteria

No.	Evaluation Criteria
1	text readability letter size14 pt
2	text readability letter size 22 pt
3	text readability letter size 26 pt
4	text readability letter size 34 pt

For this purpose, the Likert scale was used. The questionnaire consisted of four questions. Users have been evaluated text by assigning values from 1 to 7, where 1 means that user strongly disagree, and 7 that user strongly agree (Table 3).

Table 3. Validation scale

No.	Criteria/Scale
1	Text in regular cut 14 pt on Web site is readable: Strongly disagree 1 2 3 4 5 6 7 Strongly agree
2	Text in regular cut 22 pt on Web site is readable: Strongly disagree 1 2 3 4 5 6 7 Strongly agree
3	Text in regular cut 26 pt on Web site is readable: Strongly disagree 1 2 3 4 5 6 7 Strongly agree
4	Text in regular cut 34 pt on Web site is readable: Strongly disagree 1 2 3 4 5 6 7 Strongly agree
5	Text in bold cut 14 pt on Web site is readable: Strongly disagree 1 2 3 4 5 6 7 Strongly agree
6	Text in bold cut 22 pt on Web site is readable: Strongly disagree 1 2 3 4 5 6 7 Strongly agree
7	Text in bold cut 26 pt on Web site is readable: Strongly disagree 1 2 3 4 5 6 7 Strongly agree
8	Text in bold cut 34 pt on Web site is readable: Strongly disagree 1 2 3 4 5 6 7 Strongly agree

4 Results

The primary objective of the study is to perform readability evaluation of web text on four tested devices (WTOTD). The results were validated by evaluation set of criteria affecting the readability of web text. The main goals of this study have to obtain readability score of each criteria and due to analyzed results make appropriate conclusions which could lead to better understand responsive environment design.

In process of defuzzification two methods were used: Center of Gravity Method (COG), and Centre of Sums Method (COS). Other possible methods are Centre of Largest Area (CLA), Weighted Center of Area (WCA), Weighted Average Method (WAM), Maxima Methods (MM) etc. [11].

Center of Gravity (COG) method is calculated using a formula:

$$X = \frac{\sum_{i=1}^{n} x_i \cdot \mu(x_i)}{\sum_{i=1}^{n} = \mu(x_i)} \quad (4)$$

Centre of Sums (COS) method is calculated using a formula:

$$X = \frac{\sum_{i=1}^{N} A_i \cdot \overline{x}_l}{\sum_{i=1}^{N} = \mu(x_i)} \quad (5)$$

Centre of Sums (COS) method was used as a control method.

Five users evaluated readability of displayed web text on four different devices. Users were not classified by age, sex, education level or other criteria.

There is no one score below average value (Tables 4 and 5). Also is visible that the average scores of two different defuzzification methods are very similar. COS method produced slightly lower scores than COG method.

Table 4. Results by tested devices/regular cut

Score	WTOTD	COG	COS
1st	SM devices	98.13	96.21
2nd	MD devices	93.47	91.79
3rd	XS devices	89.38	87.23
4th	LG devices	79.53	77.16

Table 5. Results by tested devices/bold cut

Score	WTOTD	COG	COS
1st	SM devices	98.43	85.31
2nd	MD devices	94.92	81.03
3rd	XS devices	90.67	74.14
4th	LG devices	69.88	72.91

Further SUS score was calculated. SUS score or System Usability Scale score giving a global view of subjective assessments of system usability in order that users evaluate the fact by choosing the value of scale in simple questionnaire. SUS score is not percentage, it is calculated by the formula based on several different aspects. SUS score >80.30 means excellent adjective rating, 68.00–80.30 good adjective rating, 68.00 okay adjective rating, and 51.00–68.00 poor adjective rating (Tables 6 and 7).

Table 6. Results of validation/regular cut

Score	WTOTD	Evaluation No.				COG	SUS
		1st	2nd	3rd	4th		
User 1	XS devices	5	6	7	6	86.29	84.00
	SM devices	7	7	7	7	97.14	98.00
	MD devices	6	6	7	7	89.22	91.00
	LG devices	5	6	6	5	78.93	77.00
User 2	XS devices	5	7	6	5	83.04	80.50
	SM devices	6	7	7	7	96.19	98.00
	MD devices	6	6	6	6	85.29	84.00
	LG devices	4	5	5	4	91.56	63.00
User 3	XS devices	6	6	5	5	75.92	77.00
	SM devices	6	7	7	6	94.27	91.00
	MD devices	5	6	5	6	79.17	77.00
	LG devices	5	5	4	4	62.96	63.00
User 4	XS devices	6	6	6	5	79.53	80.50
	SM devices	6	7	7	6	94.32	91.00
	MD devices	5	5	5	4	65.48	66.50
	LG devices	4	5	5	5	62.12	66.50
User 5	XS devices	6	7	6	6	88.65	87.50
	SM devices	7	7	6	6	94.43	91.00
	MD devices	6	6	5	5	78.26	77.00
	LG devices	4	5	5	5	64.97	66.50

Table 7. Results of validation/bold cut

Score	WTOTD	Evaluation No.				COG	SUS
		1st	2nd	3rd	4th		
User 1	XS devices	6	7	7	6	93.29	91.00
	SM devices	7	7	7	7	97.09	98.00
	MD devices	6	7	7	7	95.92	94.50
	LG devices	5	5	4	5	64.88	66.50
User 2	XS devices	6	7	6	5	83.12	84.00
	SM devices	7	7	7	6	94.24	94.50
	MD devices	6	6	5	6	83.15	80.50
	LG devices	4	5	4	4	60.83	59.50
User 3	XS devices	6	6	6	5	82.41	80.50
	SM devices	7	7	7	6	91.13	94.50
	MD devices	5	6	6	6	84.23	80.50
	LG devices	5	5	5	4	59.28	66.50
User 4	XS devices	6	6	6	6	88.96	84.00
	SM devices	7	7	7	6	92.78	94.50
	MD devices	5	6	5	4	75.31	70.00
	LG devices	4	5	5	4	64.02	63.00
User 5	XS devices	6	6	6	6	86.91	84.00
	SM devices	7	7	6	6	94.98	91.00
	MD devices	5	6	5	5	75.71	73.50
	LG devices	4	5	4	5	65.47	63.00

The results of chosen WTOTDs evaluated by both methods show very good level of consistency. Some different might be caused by lover precision of the SUS score method or by user's biological predispositions such visual impairments or dyslexia. This point of view could expand this research.

Given results shows the higher score for text written with handwritten font in bold cut, font size 22 pt and 26 pt displayed on small devices. The lower score is achieved for text written with handwritten font in regular cut, font size 14 displayed on extra small devices.

5 Conclusion

The interaction between users and multimedia content on different devices requires intelligence systems for clusters of similar data that can be used to optimize and customize content for each user and each device as well. Therefore, it is necessary to know the possibilities of responsiveness to increase readability of web text on the different screen sizes, especially the extra small ones. This is very important for handwritten fonts that are not so common in web design, but it is precisely the need for personalization that is putting them to use more and more often.

So, this model of handwritten font sizes readability can be recommended for web prototype testing because gives the perfect opportunity to properly test web design before the launch of web site. The same analogy can be used for other elements of web site such as photos, animations, colors, content management system elements etc.

For the end of conclusion, it is important to note that the results of this research can be significant for creating content for users with different accessibility characteristics such as older age groups, users with visual impairments and dyslexia as it facilitates their consumption of web content.

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