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An Analysis of the Visual Complexity on Academic Library Websites Based on Berlyne's Complexity Theory

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ABSTRACT

Computational aesthetics is a field that combines science and art to explore aesthetic measurement, generative art, and design generation using computational methods. In the context of university library websites, adhering to aesthetic standards, particularly focusing on "moderate visual complexity," could enhance their visibility online (according to some previous studies). This research, analyzed 82 university library websites, including top international and Iranian academic libraries, to assess visual complexity based on Berlyne's theory of stimulus complexity using the Athec Python library. The study found that international university libraries have a complexity of over 0.57, while Iranian academic libraries lack the minimum complexity needed to motivate users. Moreover, the study found significant differences between the library websites of top Iranian and international universities. The linear regression statistic test was used to analyze the relationship between the visual complexity of academic library websites and the rank of the university, revealing a significant difference for the 41 top Iranian universities but not for the 41 top international universities. The Beta coefficient of linear regression between the visual complexity of academic library websites and the rank of the university is -0.502, and Sig=0.001, obtained for the top Iranian universities. On the other hand, the Beta coefficient of linear regression between the visual complexity of academic library websites and the ranks of the university is -0.062, and Sig=0.701, obtained for top international universities. This research highlights the innovation of connecting Berlyne's theory of stimulus complexity with Python programming, providing a new perspective for university library website managers.

Keywords*— Computational Aesthetics, University Libraries, Aesthetic Perception, Human Computer Interaction, User Experience.*

1. Introduction

Computational aesthetics is emerging as a bridge between science and art and is an emerging interdisciplinary field [1]. When beauty in the field of art is combined with the understanding of beauty by a machine, it takes the name of computational aesthetics. In other words, computing beauty is when it takes a measurable form, i.e., in the field of human-computer interaction, it is supposed to be understood by the computer in the web environment to understand beauty like a human.

The word aesthetic is derived from the Latin word "aisthitiki" which means "understanding through feeling". Aesthetics is defined as "pleasant appearance"[2]. Aesthetics has only one principle and it is "observance of unity in diversity"[3]. Moreover, according to Nielsen [4], the aesthetic of the user interface (UI) is one of the most important principles.

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Based on Lang [5], aesthetics is divided into formal and symbolic. Formal (classic aesthetic) features such as forms, proportions, rhythm, scale, levels of complexity, color, light, shadow, etc., and symbolic aesthetics (expressive aesthetic) are influenced by each culture and interpreted and defined in the meaning they evoke [6].

The origin of the concept of computational aesthetics dates back to 1928 when the American mathematician George David Birkhoff proposed M = O/C at Harvard University [7]. Indicator, M is an aesthetic measure, O is a measure of the order of the information object, and C is a measure of the complexity of the information object [8].

By using "exploratory factor analysis", Lavie and Tractinski [9] found that the perception of web users in the field of "human-computer interaction" consists of two main dimensions: "classic aesthetics" and "expressive aesthetics". The dimension of classical aesthetics is related to the aesthetic concepts that prevailed from ancient times to the 18th century.

Due to the development of science and technology, university library websites need to be seen in the web environment. According to Bowen [10], libraries should pay attention to the aesthetic perception of users in the web environment. Increasing aesthetics is one way to highest visibility. Because users enjoy the beauty and choose to visit the library website. Based on Berlyne's theory, the complexity of an information object should be neither too low nor too high to make it look beautiful to the person who perceives it [11]. Therefore, for academic library websites to attract users, they should have the minimum necessary visual complexity. It is to be noted that this mentioned factor, is one of the most components of visual aesthetics. Other factors such as unity, organization, layout, and so on.

According to one experimental study on the number of 40 users and the driving factors in 30 websites by Schmidt and Wolff [12], "visual complexity" can be considered the strongest predictor for the aesthetic judgment of web users. Therefore, this mentioned factor is selected for aesthetic analysis (moderate complexity) of the university library websites. The feature of moderate complexity is reported as an important factor of aesthetics in several studies [9, 11, 13, 14, 15, 16, 17, 18, 19].

Tuch, Bargas-Avila, Opwis, and Wilhelm [20], while studying the number of 36 web page photos, found that the "visual complexity" of websites has many effects on human cognition and emotions and even increases the heart rate of users. The importance of university library websites in attracting users and increasing visibility in the web environment is not hidden from anyone because they play an important role in the growth and development of science and knowledge. Therefore, the aesthetic of the main pages of university library websites, which attracts users is important and one of the main goals of university library managers [21].

Peng [22] proposed the Athec Python library and considered it essential for humanities research and their combination with computer science. In the present research, the visual complexity value of 0.5 (edge density + edge box size = 0.5, on the Athec python library) is assumed to be the minimum normal for aesthetic perception based on Berlyne's complexity theory.

In this present research, the primary assumption is that the number of edges in the Python Athec library measures the complexity of a photo (screenshots of the main pages of the academic library websites) correctly. Moreover, it is assumed that the value of minimum visual complexity that leads to emotional stimulation of web users is 0.5.

1.1. Research Questions

- What is the status of the international's top university library websites from the standpoint of visual complexity? (Plus, comparative analysis of them).
- What is the status of the Iranian's top university library websites from the standpoint of visual complexity? (Plus, comparative analysis of them).
- Comparative analysis of International and Iranian university library websites.
- Correlation analysis between university rank (Times Ranking 2023) and visual complexity of best international university library websites.
- Correlation analysis between university rank (ISC Ranking 2021) and visual complexity of best Iranian university library websites.

2. Literature Review

Peng [22] utilized Athec Python library for the analysis of images of Instagram posts of political people from the standpoint of visual complexity and computational aesthetics and recommended using this mentioned library for social sciences studies.

A multivariate analysis of covariance from Tractinsky, Katz, and Ikar [23] has shown that the "aesthetic degree of the system" affects the "use of the same system after understanding the aesthetics" and thus the "increasing the level of usability", While the converse is not true, i.e., "actual degree of usability (applicability)", it does not have such a similar effect on enhancing aesthetics.

According to Michailidou, Harper, and Bechhofer [24], there is a relatively strong correlation between users' perception of visual complexity, structural elements (links, images, words, and sections), and

aesthetic perception (organization, clarity, cleanliness, attractiveness, and beauty) of a web page.

Mbipom [25], recommended a conceptual model for the division of the aesthetic components of websites, with an exploratory evaluation approach by 11 website experts and also using the conceptual model proposed by Lavie and Tractinsky [9].

Based on Sedghi Shamir [26], considering the aesthetic components while designing a website leads to a decrease in the "bounce rate of the users", and as a result, an increase in web visibility.

Wong and Bowerman [13] argued that in addition to being usable, websites should also be enjoyable to look at. However, a lot of research has been done on usability, and psychological aesthetic issues in the web environment have been much less investigated. In addition, Wang and Bowerman [13] while studying 132 children about 12 years old found that there is an inverted U-shaped relationship between the subjective aesthetic preference of a stimulus and its complexity. Overall, children prefer web pages with moderate visual complexity from an aesthetic point of view, and this is consistent with Berlyne's complexity theory.

According to Wang [18], the number of 45 male children were compared with 45 female children from the perspective of aesthetic preference of web pages, and boys preferred a high level of visual complexity, while for girls, a medium level of visual complexity led to their aesthetic enjoyment of web pages. Berlyne's theory of complexity has been confirmed to some extent in this mentioned study. The tool used by the aforementioned researchers was a questionnaire consisting of two parts, the objective beauty of the website design and the subjective perception of the website.

Chevalier, Maury, and Fouquereau [27] argued that the users who were not familiar with the website in advance evaluated it as more beautiful than the participants who were familiar with it. Another finding of the aforementioned researchers is that "usability" has no significant correlation with "expressive aesthetic factors".

Lazard, Watkins, Mackert, Xie, Stephens, and Shalev [28], during a study, invited 38,000 patients to participate in aesthetic research about their disease portal. 8000 patients consented. They used the website aesthetic perception questionnaire of Moshagen and Thielsch [3]. They concluded that the aesthetic components have a strong effect on the patient's use of their electronic portal on the web. has it. The component of "simplicity" and lack of complexity is known to be the most important factor of website aesthetics.

Seckler, Opwis, and Tuch [29] found that the websites with high symmetry, low complexity, blue color, medium brightness, or medium and high saturation received the highest overall aesthetic ratings.

Zohreh Vandi and Emamifar [30] examined the 21 web pages from the website of the Iranian television channel (IRIB, TV1), and considered the use of the "golden ratio" to be effective in the aesthetic perception of the users toward the web pages. According to Bo, Yu, and Zhang [1], the ratio of two-line segments a and b to each other is equal to the golden ratio if Equ(1):

$$\frac{(a+b)}{a} = \frac{a}{b} \cdot \frac{1+\sqrt{5}}{2} \qquad (1)$$

Based on research with a descriptive-analytical approach and a case study of the "Official Website of Iranian Newspapers", by Rouzbahani, Afhami, and Abdolvand [31], the visual design components of web pages have a significant effect on the aesthetic perception of the audience or users. Moreover, the "unity" component is the only factor that affects all aspects of aesthetics (among the three structural factors "unity", "diversity" and "dynamism").

Jiang, Wang, Tan, and Yu [32], proposed a framework consisting of five aesthetic components for a website using the card sorting method during a pilot study. In the mentioned framework, the five essential design elements to comply with the aesthetics of the website are unity, visual complexity, intensity, freshness, and interactivity.

Redi, Liu, and O'Hare [14], in a speech at the World Conference on Multimedia Retrieval, while analyzing 100,000 web pages, proposed a computer model with a machine learning approach called "Ava Deep" that analyzes the aesthetics of digital photos. Aesthetic components in this mentioned research, are "Sharpness and clarity of the edges of digital images", "Compatibility of the photo with the texture", "Balance (placing the information content of the image in the middle of the content of the photo instead of the left and right of the photo)", "Color", "saturation" and "proper lighting".

Boychuk and Bakaev [33] surveyed 70 web users of the 497 web pages using MATLAB software and analyzed the entropy index of web pages and found that the information entropy of web pages has a significant correlation with the aesthetics of the same web pages as well as the order of said pages. However, they did not see a significant relationship between the two indicators of the size of website images and the entropy of website images. It is worth mentioning that they have included screenshots of the website pages.

By the MANOVA analysis of multivariate analysis of variance on 277 subjects, the high level of visual complexity, as well as the medium (moderate)

complexity of the website, has led to more aesthetic perception than the website on the Lazard and King [34].

Gabrieli, Bornstein, Setoh, and Esposito [35] argued that colorfulness and visual complexity are among the explicit aesthetic components of a web page for a website or a digital photograph. In conducting their research, the aforementioned researchers have used the Python library called "PyAesthetic" which was proposed by Gabrieli in 2019.

3. Methodology

The current research has been carried out in terms of practical purpose and with an analytical survey approach.

Athec python library calculated the visual complexity of images in one of its features (Edge feature). In this study, images (screenshots) of homepages of academic library websites (Iranian and international) were extracted and used to input of Athec python library proposed by Peng [22].

Edge detection is one of the new methods in image processing [36]. The present research has analyzed the image of the home page of university library publications from the point of view of the edge factor that exists in the Python Attec library.

3.1. Data Features

The number of top (ISC scientific ranking) forty-one Iranian university libraries compare with the number of top (Times scientific ranking) forty-one international university library websites. In terms of mathematical principles, correlation and regression analysis are valid for the research population of more than 40 items. In fact, the research community of less than forty damages the validity of the analysis. Here, 41 library websites of top Iranian universities have been compared with 41 library websites of top international universities, from the standpoint of visual complexity.

First, top the 41 international universities were identified based on the Times ranking. Moreover, 41 top Iranian universities were recognized based on the ISC ranking. Then, the websites of the mentioned libraries, i.e. 82 websites, were identified. Then, the screenshots were taken from the main page of the library's websites and given as the inputs to the Athec Python library (PNG), and the outputs were extracted. All of the screenshots were of the same size, approximately, width = 1880 pixels, height = 800 pixels. The type of them was PNG, in order not to lose digital information. For measuring visual complexity, the Edge indicator on the Athec (edge density + edge box size) has been used.

In Excel, draw the complexity graphs of university library homepages according to their universities' ranking (Figure 1, and Figure 2).

The significant difference analysis of two groups of library websites of top international (41 library websites) and Iranian universities (41 library websites) was done with SPSS software. Correlation analysis between the rank of universities and the complexity of their library homepages was done with SPSS.

It is worth noting that the Python Atthec library [37], proposed by Peng [22], had problems while outputting the 82 photos from university library websites. Therefore, its developed version (Athec-developed version [38]) was used.

4. Findings

The websites of the Iranian and International university libraries were analyzed. In both Figure 1 and Figure 2, the column is the visual complexity of university library websites and the row is the rank of their university (Iranian based on ISC ranking and International based on the Times ranking).

Edge indicator (density complexity + box size complexity) on the Athec Python library, calculated for the research community (main pages of the international and Iranian university library websites). Athec program has seven indicators, saliency, preprocess, edge (complexity), sharp, shape, segment, and color.

According to Figure 1, the scores of all the best international university library websites (based on Times ranking) have more than 0.57 was obtained from the standpoint of visual complexity. Moreover, this digit was more than 0.39 for the library of Iranian universities. This result means that they have the minimum necessary complexity that leads to beauty and stimulates the user's feelings (more than 0.5). But, Iranian academic libraries lacked the minimum complexity needed to motivate users, according to Berlyne's theory. Digits from 1 to 41 on Figure 1, and Figure 2 are ranks of the university.

Kolmogorov-Smirnov test was done for the visual complexity of the 41 academic international university library websites, and the visual complexity of the 41 academic Iranian university library websites.

According to Table 1, the digits of the complexity of the 41 Iranian university library websites have a normal distribution (sig of Kolmogorov normality test = 0.2 > 0.05). In addition, the digits of the complexity of the 41 international university library websites have not a normal distribution (sig of Kolmogorov normality test = 0.041 < 0.05).

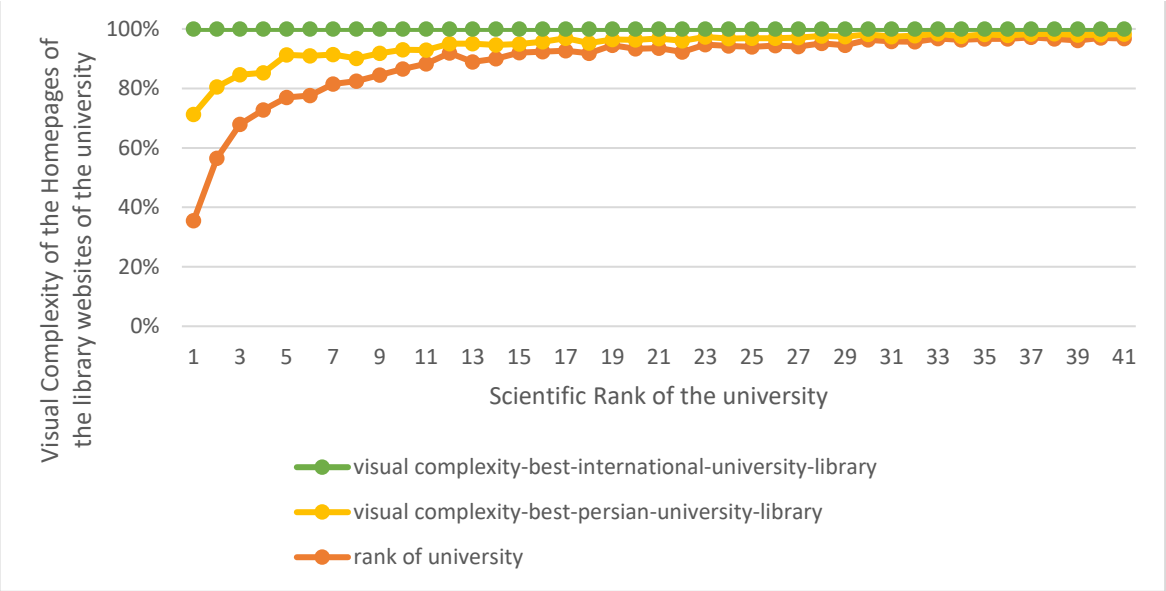


Figure. 1. The visual complexity of the 41 best International and Iranian academic library websites, regression view

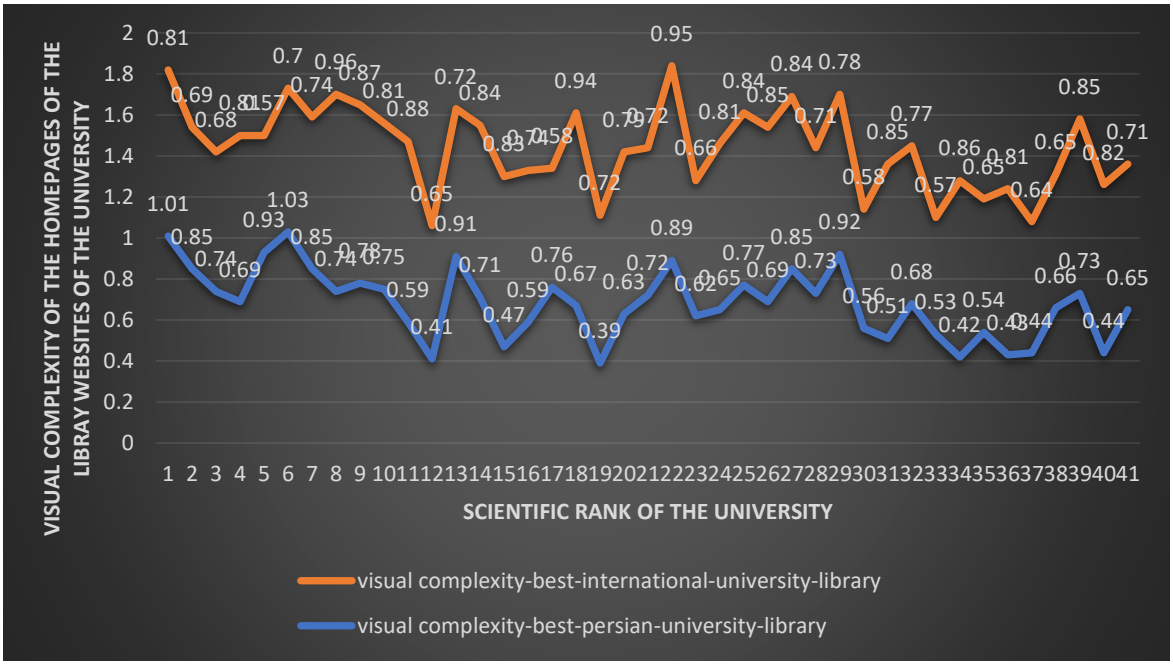


Figure. 2. The visual complexity of the 41 best International and Iranian academic library websites, comparative view

Based on Table 2, the Spearman correlation test, there was no significant correlation between the visual complexity of the library websites of top Iranian universities and top world universities (sig = 0.671 > 0.05).

Because of the normality distributions of the university ranking (1 to 41), and the visual complexity of the Iranian university library websites (Table 1), the Pearson correlation test is suitable and responsive. According to Table 3, a weak reverse significant correlation (sig = 0.01 <= 0.01; Pearson correlation test = -0.502) between the ranking of Iran's top universities and the degree of visual complexity of their library websites, was obtained. The inverse relationship seems logical. The higher the visual complexity of the university library website, the less beautiful it becomes, and the less attracted web users are to beauty, and the lower the ranking of the university. Of course, a moderate level of complexity (not too little and not too much) is appropriate according to Berlyne's theory.

Because of the normality distributions of the

university ranking (1 to 41), and the non-normality of the visual complexity of the international university library websites (Table 1), the Spearman correlation test is suitable and responsive. According to Table 4, there is no significant correlation (sig = 0.804 > 0.01)

Table 1. Tests of Normality. Complexity of the homages of the Iranian and international academic library websites

Variables	*Kolmogorov-Smirnov* [a]		
	Statistic	*df*	*Sig*
complexity.Iranian.university.library.websites	0.070	41	0.200 *
complexity.International.university.library.websites	0.140	41	0.041

[a] Significance Correction.

Table 2. Correlations between visual complexity of the International and Iranian Academic Library websites

Correlation test	*Spearman's rho*		
	Variables	*Iranian university libraries*	*International university libraries*
complexity.Iranian.university.library.websites	Correlation Coefficient	1.000	0.068
	sig		0.671
	N	41	41
complexity.International.university.library.websites	Correlation Coefficient	0.068	1.000
	sig	0.671	
	N	41	41

Table 3. Pearson Correlation test between the rank of the top 41 Iranian universities, and the visual complexity of their library websites

Variables	*Pearson Correlation test*		
	Indicators	*The visual complexity of Iranian library websites*	*The rank of the university*
Visual complexity of Iranian library websites	Pearson Correlation Coefficient	1.000	-0.502 [a]
	Sig. (2-tailed)		0.01
	N	41	41
Rank of Iranian University (ISC ranking)	Pearson Correlation Coefficient	-0.502	1.000
	Sig. (2-tailed)	0.01	
	N	41	41

[a] Correlation is significant at the 0.01 level (2-tailed).

between the ranking of international top universities and the degree of visual complexity of their library websites (Table 4).

Based on the Wilcoxon signed ranks non-parametric test displayed in Table 5, the similarity of the visual complexity of the university library websites of Iranian and international groups was rejected (0.010 <= 0.01). This result is another confirmation of the difference between the two library groups of top Iranian and international universities in terms of visual complexity.

In the analysis of the significant difference between the visual complexity in the group of top international universities (according to Times ranking) with the Kruskal Wallis test, the dependence of the visual complexity of the university library website on the university rank was rejected (Figure3). This result was also obtained from the library website of top Iranian universities (according to ISC ranking) (Figure4).

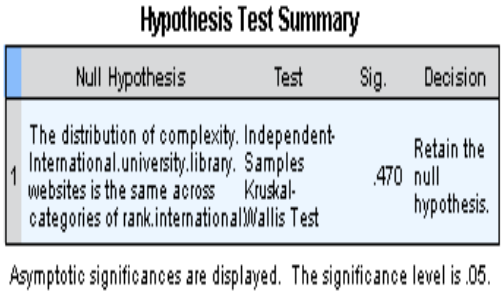
Table 3 and Table 4 indicate that there is no significant relationship between the academic rank of universities and the visual complexity of their library websites (screenshots of their homepages).

Linear regression analysis was done and Table 6, Table 7, and Table 8 were obtained.

According to Table 7, the Beta coefficient of linear regression between the visual complexity of academic library websites and the rank of the university is -0.502, and sig < 0.05 <= 0.01 was obtained for the top Iranian universities.

Table 4. Spearman Correlation test between the rank of the top 41 international universities, and the visual complexity of their library websites

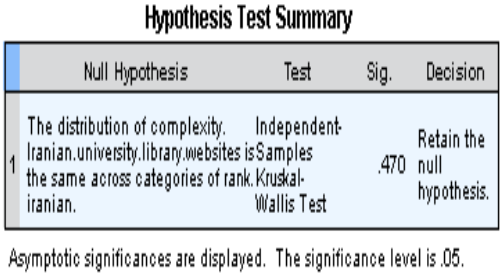
Variables	*Spearman Correlation test*		
	Indicators	*The visual complexity of international library websites*	*The rank of the university*
Visual complexity of international library websites	Spearman Correlation Coefficient	1.000	-0.040 [a]
	Sig. (2-tailed)		0.804
	N	41	41
Rank of international University (Times ranking)	Spearman Correlation Coefficient	-0.040	1.000
	Sig. (2-tailed)	0.804	
	N	41	41


Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of complexity. International.university.library. websites is the same across categories of rank.international.	Independent-Samples Kruskal-Wallis Test	.470	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure. 3. Kruskal Wallis's analysis of visual complexity of the top 41 international university library websites among the ranking group of their universities


Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of complexity. Iranian.university.library.websites is the same across categories of rank. iranian.	Independent-Samples Kruskal-Wallis Test	.470	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure. 4. Kruskal Wallis's analysis of the visual complexity of the top 41 Iranian university library websites among the ranking group of their universities

Table 5. Wilcoxon Signed Ranks Test between visual complexity's websites of the academic library of two groups, international and Iran from the standpoint of visual complexity

Variables	***Wilcoxon Signed Ranks Test***
	The complexity of Iranian university library websites – the complexity of international university library websites
Z	-2.561 [a]
Asymp. Sig. (2-tailed)	0.010

[a] Based on positive ranks

Table 6. Model Summary (linear regression)

Model	***Variables***			
	R	***R Square***	***Adjusted R Square***	***Std. Error of the Estimate***
1	.502[a]	.252	.233	10.492
2	.062[b]	.004	-.022	12.109

a. Predictors, complexity.Iranian.university.library.websites
b. Predictors, complexity.international.university.library.websites

Table 7. Coefficients between visual complexity of library websites and scientific ranking of the top 41 Iranian universitiesa

Model		***Unstandardized Coefficients***		***Standardized Coefficients***	***t***	***Sig***
		B	***Std. Error***	***Beta***		
1	(Constant)	45.314	6.904		6.564	0.000
	Visual complexity of the Iranian.universitylibrary websites	-35.692	9.844	-0.502	-3.626	0.001

[a]. *Dependent Variable: rank of the top Iranian universities (ISC ranking)*

Table 8. Coefficients between visual complexity of library websites and scientific ranking of the top 41 world universitiesa

Model		***Unstandardized Coefficients***		***Standardized Coefficients***	***t***	***Sig***
		B	***Std. Error***	***Beta***		
2	(Constant)	26.410	14.138		1.868	0.069
	Visual complexity of the international universitylibrarywebsites	-7.098	18.382	-0.062	-.386	0.701

[a] *Dependent Variable: rank of the international universities (Times ranking)*

According to Table 8, the Beta coefficient of linear regression between the visual complexity of academic library websites and the ranks of the university is -0.062, and sig > 0.05 >= 0.01 was obtained for top international universities.

Therefore, there are significant differences between Iranian and World University library websites from the standpoint of their visual complexity according to screenshots of their main pages based on edge indicators of the Athec Python library.

5. Conclusions

This present study opted for the approach of computational aesthetic analysis. Moreover, one of the most important factors affecting it, moderate

visual complexity, was investigated. In this study, only the first page of the university library website was analyzed. This is a limitation of the research. But in general, it opens a new perspective for further research. University library website managers, in linewith the development of science, it is better to increase the aesthetic appeal of their website. Having moderate complexity is one of the criteria for aesthetics based on [9, 11, 13, 14, 15, 16, 17, 18, 19].

In the present research, the websites of international university libraries had a moderate complexity that leads to the excitement of users' aesthetic perception. But the library websites of Iranian universities did not have the minimum complexity to attract users based on Berlyn's driving complexity theory. Examining and analyzing other features of a library website, apart from the complexity criterion, is recommended in future research.

Considering that the main page of university library websites was analyzed in the current research, it is a kind of limitation. But the results are usable. In addition, many kinds of research have been published with this mentioned method, such as Boychuk and Bakaev [33] and Mbipom [25].

The current research emphasizes the interaction between three groups of experts in computer science, social science, and cognitive psychology.

The innovation of this research is the connection of Berlyne's theory of stimulus complexity with programming. Moreover, this present study is a new perspective for managers of academic library websites in the world. In addition, an analysis of the relationship between search engine optimization (SEO) and visual complexity on university library websites is recommended.

It is suggested to use a larger sample and parametric statistical tests in another research (more than 41 websites). Moreover, an analysis of public university library websites, and medical library websites is recommended.

Declarations

Ethical Approval

This research is extracted from a doctoral dissertation that has received a confirmed code from the Research Ethics Committee Certificate of Kharazmi University (Approval ID is IR.KHU.REC.1402.127).

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Authors' contributions

In Maryam Tavosi: Conceptualization, Methodology, Formal Analysis, Validation; Visualization, Writing - original draft. Nader Naghshineh: Investigation, Supervision, Writing - review & editing. Mohammad Zerehsaz: Conceptualization, Methodology. Siamak Mahboub: Conceptualization, Methodology

Conflict of interest

The authors declare that no conflicts of interest exist.

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